Journal of the Royal Society of Arts

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BROADCAST FROM THE SOCIETY'S HOUSE

Fellows of the Society are to have an interesting opportunity of taking part in a discussion programme which is to be broadcast in the General Overseas Service of the B.B.C. The discussion, which will be recorded in the Society's Lecture Hall at 8 p.m. on Tuesday, 22nd June, is part of a series entitled *Serious Argument*, in which questions on topics of international and domestic importance which have been in the headlines during the previous week are raised by members of the audience, and on this occasion they will be discussed by the Right Honble. Walter Elliott, C.H., F.R.S., M.P., and the Right Honble. James Griffiths, M.P.

Fellows are invited to apply for tickets for admission for themselves and not more than two guests, not later than Saturday, 5th June.

VISIT TO LONGFORD CASTLE AND SOIRÉE AT THE SOCIETY'S HOUSE

Fellows are reminded that if they would like to receive an invitation to the At Home at Longford Castle, on 3rd July, they should inform the Secretary of the Society *by Saturday, 5th June*. They are also asked to inform the Secretary *by 5th June* if they wish to be present at the informal reception which will be held at the Society's House on the evening of Wednesday, 30th June. A notice about both these events was published in the last issue of the *Journal*.

PROGRAMME FOR THE 201ST SESSION

The Council will shortly be considering the programme of meetings for the forthcoming session, and Fellows are invited to forward to the Secretary suggestions for lectures and papers by 12th June.

EXHIBITION OF BURSARY DESIGNS

The exhibition of designs submitted in the Society's 1953 Bursaries Competition now being held in the Society's House will remain open until Friday, 4th June. The exhibition includes a selection from some of the designs submitted in the Society's first competitions in the eighteenth century.

SAFETY IN TRANSPORT

Three Cantor Lectures

I. SAFETY ON THE ROAD

by

W. H. GLANVILLE, C.B., C.B.E., D.Sc., M.I.C.E.,

Director of Road Research, Department of Scientific and Industrial Research

Monday, 22nd February, 1954

In the three Cantor Lectures which I had the honour of delivering to your Society at the end of 1950 I gave an account of the research into road safety and traffic in hand at the Road Research Laboratory. On this occasion my lecture has a broader title and, in keeping with this, I will try to treat the subject more generally.

In many respects the road safety problem is not unlike other public health problems, problems which have also largely grown with the industrial and technological development of the past one hundred years or so. But whereas many of these problems have been solved or are on their way to solution, in the sense that we are providing ourselves with a healthier environment and way of life, we still maintain a system of moving ourselves and our goods on our roads which caused over 5,000 deaths and over 220,000 injuries last year.

We have healthier houses with less overcrowding. We have good water supplies, adequate sanitation, strict factory regulations, and at least we are trying to consume cleaner food and breathe cleaner air. We try hard to protect ourselves against fire and the collapse of buildings and other dangers associated with crowds, and we have schemes of social insurance against poverty, death and unemployment. It would be a long story to trace progress in these individual fields. We may note, however, that the Public Health Act of 1875 opened a new era in preventive medicine which was subsequently gradually extended to a vast national policy of housing reform and town planning. Mortality began to fall about 1870 and has been reduced to half its former level in England and Wales, from 22·5 per 1,000 in 1861–70 to 11·3 in 1952.

As a result of the falling death rate, the expectation of life at birth between 1870 and 1951 has risen from 41 to 66 years for males and from 45 to 71 for females. Increased knowledge of infant welfare and child management has reduced infant mortality from 154 deaths per 1,000 live births in 1861–70 to 28 in 1952, and recent medical discoveries have depressed the death rate from infectious diseases from 522 per million in 1935 to 111 in 1950.

TABLE I. DEATH RATES PER MILLION PER YEAR ARISING FROM ACCIDENT OR NEGLIGENCE, ENGLAND AND WALES*

	1863–70	1871–80	1881–90	1891–1900	1901–10	1911–20	1921–30	1931–38	1939–45	1946–51
Males										
Mines, quarries										
Coal-mines	96	81	66	57	57	68	48	40	44	25
Other mines	13	8	4	9	9	6	4	3		
Vehicles, etc.										
Railways	71	89	62	59	47	45	24	23	26	18
Horse vehicles and horses	124	107	94	86	59	44	13	5	†	†
Other vehicles	—	—	1	4	22	75	170	235	240	159
Drowning	214	207	166	151	121	120	70	58	63	40
Burns, scalds, etc.	109	90	74	73	64	58	38	29	30	15
Females										
Vehicles, etc.										
Railways	5	6	5	4	3	3	2	2	2	2
Horse vehicles and horses	19	17	16	16	11	9	2	1	†	†
Other vehicles	—	—	0.3	1	6	21	51	75	66	49
Drowning	37	41	31	27	22	22	15	12	11	10
Burns, scalds, etc.	112	92	73	87	83	71	44	38	37	23

* Figures for 1863–1938 are taken from *Deaths by violence*, 1837–1937, by M. Greenwood, W. J. Martin and W. T. Russell, *J. Roy. Statist. Soc.* 1941, **104** (2), 146–163.
† Not known

Table I shows the way in which the rates of violent deaths arising from various forms of accident or negligence have changed.

We may ask what the driving forces behind these changes were. There is no doubt that in some cases we must thank individual reformers, who had to overcome apathy or opposition among public, parliament or private purse. Education of the people in ways of health was no doubt a powerful force. In some cases legislation could not be brought in until scientific and technological advance had paved the way.

What hope is there that these forces can be equally successful with the more recent evil of road accidents? There is nowadays no shortage of would-be reformers but there appear to be none living to-day with a voice and message which will be heeded by a rather apathetic public with many claims on its attention. And taking the broad and distant view, it seems that the people do not want to use their instruments of parliamentary democracy on this particular

job; they are more interested in other things which they consider of more economic and national importance.

To return to the closer view, are there any comparisons with these other public health problems which are of value? If they are examined in a little more detail it will be seen that an integral part of the process is the exercise of some degree of control of the danger unit concerned, and the fixing of the responsibility for exercising that control. The danger unit may be the mine, the dwelling, the factory or a particular kind of machine; it may be the food we eat, the water we drink, and so on. Generally it has been possible for the responsibility of keeping these units under surveillance to be fixed on the owner, the distributor, the local authority or some other body.

But the corresponding danger units in the road accident field are the vehicles and pedestrians in motion.* The comparison is largely between static and dynamic units, between those sources of danger on which we keep a constant watch and those to which we give very considerable freedom.

Will the social historian of the future look back on the second half of the twentieth century as a period during which the public attitude to the subject changed so that it was said 'Here was a freedom which was abused'? Will the nation take the necessary measures to remove threats to public health in the same way as it learned to accept, to believe in, and to pay the initial cost for, the measures in other fields? Time will tell.

COMPARISON OF RISKS IN DIFFERENT FORMS OF TRANSPORT

Before proceeding with a more detailed analysis of the question we should, I think, look at a few comparative figures between different forms of transport. When you are about to make a journey you may be able to choose between various forms of transport. You may be able to drive a car or van, ride a motor-cycle or a pedal cycle, or go by train or by air. Your relative chances of death or injury in each of these methods of travel are given in Table II.

TABLE II. RELATIVE RISKS IN UNDERTAKING A JOURNEY PER PERSON-MILE (1948–1952)

Type of traveller	*Relative risk of:*	
	death	*non-fatal injury*
Driver of 4-wheeled vehicle	1	60
Motor-cyclist	40	1,230
Pedal-cyclist	15	800
Passenger in train (or passenger on station premises and hit by train)	0·5	30
Passenger in U.K. scheduled airways ...	3·7†	0·2

* In railway transport we have insisted on a high degree of segregation between danger units so that each unit is under effective control.

† Owing to the small number of accidents to air passengers in any year and to the fact that in each air accident a relatively large number of people may be involved, it is difficult to work out accurate rates for fatal accidents to passengers. The figures in Table II have been obtained by taking averages over five years but in 1951 and 1952 there were, in fact, no fatal accidents.

From these figures it appears that your chances of being killed are least if you travel by train, they are seven times as great if you choose air, twice as great if you drive a motor vehicle, thirty times if you cycle, and eighty times if you risk death on a motor-cycle. Risks of a non-fatal injury are similarly related to each other except for air travel where the risk of a non-fatal injury is almost negligible.

Comparing pre-war with post-war figures the number of deaths per passenger-mile has decreased enormously for air travel. The change in the road transport rate between 1938 and to-day is not so marked although it has decreased. The rail accident rate has remained almost unchanged.

AMOUNTS AND KIND OF FUTURE TRAFFIC

What does the future hold for us? Road safety will depend on the volume of traffic, on the facilities we provide for this traffic and on how it behaves. Let us look at the volume of traffic and the growth to be expected—a subject of fundamental interest to us all, but especially to planners of new roads and road systems as well as to all improvers of existing ones. This is indeed a treacherous field for reflection for so far as I know most estimates have turned out to be gross underestimates. However, I propose to-day to bring together some of the relevant facts and to consider what might usefully be deduced from them.

The changes in vehicle registrations and in traffic flow in the past both in this country and in the United States (I choose the United States because information is readily available for that country) are shown in Figure 1. Figure 1 (*a*) gives motor vehicle registrations year by year in the two countries, and Figure 1 (*b*) gives the amount of traffic using the roads relative to 1938. You will see that between 1920 and 1938 both vehicles registered and traffic flow were increasing similarly (in proportion to their volumes) for the two countries. The post-war situation was, however, different. Even during the war the number of vehicles registered in the United States did not fall below the number in 1938, and since then has increased markedly, and is still increasing, despite the fact that the number of persons per motor vehicle is only 2·9 compared with our figure of 10. In Great Britain, however, the number of vehicles registered dropped very greatly during the war period and did not reach its pre-war level until 1947. Since then the number of vehicles registered has been increasing by about 7 per cent a year. In America the supply of new vehicles has been almost equal to the demand, but in this country supply has not yet reached demand, although the number of private vehicles reaching the home market during this last year has been greater than the corresponding number before the war. It seems likely that the present rate of increase in vehicle registrations of about 400,000 per annum will continue. We now have 60 per cent more vehicles registered than we had before the war. Another four years at the present rate of increase will give us double the number we had before the war, and, in ten years' time, nine million vehicles. However, even if the present rate of increase does not continue it seems inconceivable that the pre-war figures will not be doubled and much more than doubled in the not very distant future. The American

figure of one vehicle per 2·9 persons would mean a five- or sixfold increase over 1938 or 17 million vehicles!

The position with respect to traffic flow is rather different. We did not reach the pre-war figure for traffic flow until petrol was derationed in 1950, and in 1953 the amount of traffic on the roads at any time averaged about 30 per cent above pre-war. The United States, however, reached pre-war traffic flow in 1946 and since then flows have been increasing there at about the same rate as the number of vehicles. It is clear that the average vehicle in this country does

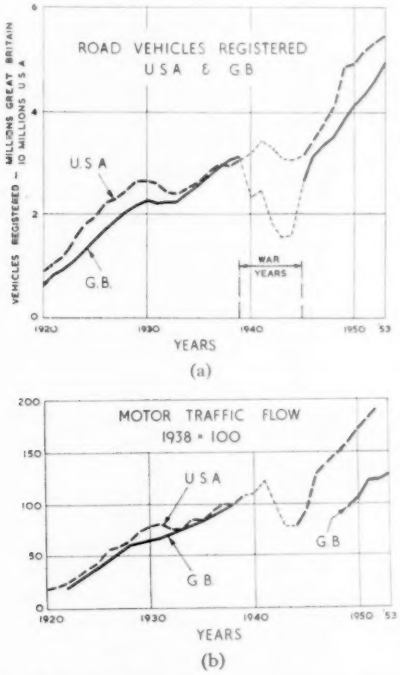

FIGURE 1. (a) *Growth in number of vehicles;* (b) *Growth in traffic*

a smaller mileage than it did pre-war. At least part of this decrease in mileage must be due to the increased cost of motoring and it is likely that mileage per vehicle will change in accordance with this cost. It seems likely that these very marked trends in traffic flows will continue. It is worth noting in this connection that, although the world economic slump in 1929 resulted in a halt for a short time in the increase in the numbers of vehicles registered and in the vehicle mileage, it did not result in a drop and the increase started again in 1931. It

seems to me unwise not to assume that there will be very substantial increases in the vehicle registrations and traffic flow in this country, especially as it seems likely that the cost of motoring will decrease in comparison with the cost of many other commodities.

ACCIDENTS

How will a large increase in the number of vehicles using the roads affect the frequency of road accidents? It is obvious that there will be many more accidents unless something is done to prevent them. This is well illustrated in Figure 2, which shows the number of casualties from road accidents in Great Britain year by year since 1910. There has been a strong tendency for the number of road casualties to rise year by year. The only periods in which there have been falls in the number have been between 1915 and 1918, between 1934 and 1935, between 1938 and 1943, between 1947 and 1948 and between 1951 and 1952.

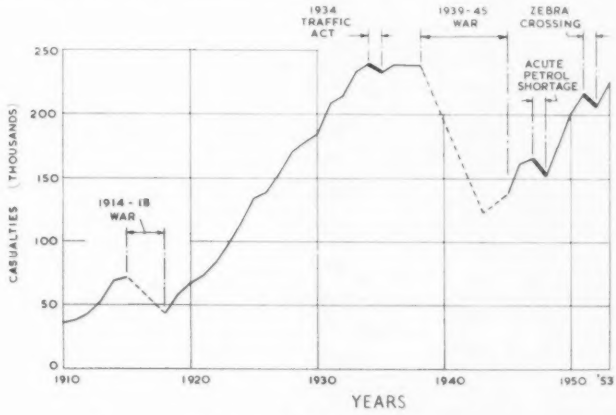

FIGURE 2. *The growth of road casualties, 1910–1953*

The first and third of these periods are accounted for by the First and Second World Wars; the second drop was almost certainly the result of the 1934 Road Traffic Act; the drop between 1947 and 1948 was due to the complete prohibition of petrol for private purposes, and the drop between 1951 and 1952 can be at least partly explained by the change in road behaviour accompanying the introduction of zebra crossings at the end of 1951. The only drops in the frequency of road casualties have in fact been due either to the reduction in the amount of traffic due to war or economic conditions or to the changes in behaviour due to active administrative measures. It is clear that since we cannot, as rational human beings, look to war or economic circumstances to solve our road accident problem the only proved course is by making administrative changes. All other measures that have been taken have merely served to reduce the rate of increase.

If accidents increase at the average rate at which they have been increasing since the war; which is not very different from the rate before the war up to 1934, we might expect in ten years' time about 330,000 casualties a year as compared with 226,000 casualties at the present time. That is, nearly one person were a casualty not more than once in a lifetime this would mean that with a life-in a hundred and fifty would become a casualty each year. If each person involved span of 75 years one person in two would become a casualty at some time in his life. If accidents were to increase directly with the numbers of vehicles the position would be worse. In ten years' time casualties might reach 450,000. Fortunately this is not to be expected.

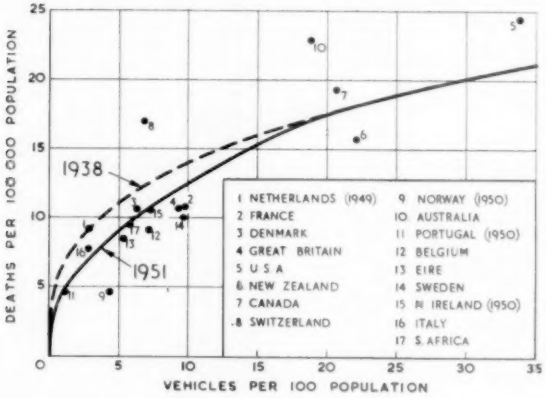

FIGURE 3. *Relation between number of deaths per 100,000 population and number of registered vehicles per 100 population for 1951*

In this connection it is of interest to compare the accident rate in Great Britain with that of other countries, but this is difficult owing to the different sizes of the population, the different numbers of vehicles and the differing lengths and characters of the roads. However it is worth while seeing how the number of fatal accidents per vehicle or per unit of population varies in the different countries. Some data on the subject can be seen in Figure 3 and Table III. It will be seen from Figure 3 that, as is perhaps to be expected, as the amount of traffic in a country increases, the proportion of the population that is killed in road accidents increases also. The rate of increase of accidents, however, is not nearly as great as the increase in the number of vehicles. It is for this reason that, as Figure 4 also shows, the number of road fatalities per vehicle registered decreases with increase in the number of vehicles using the roads. It appears that as the number of vehicles in a country increases the population

get more used to the problem that the increase of traffic entails, and become more skilled in avoiding accidents. The number of fatal casualties per vehicle registered tends therefore to decrease but not generally at such a rate as to result in a decrease in the absolute number of deaths. Although the individual points are widely scattered about the curve, for each proportion of vehicles to population there is an expected number of deaths. Great Britain, I am glad to say, is not above the average for our number of vehicles and population.

In Figure 3 and in Figure 4 two curves are shown. The dotted curve relates to 1938 figures and the full one to 1951. It is significant that the later curve is the lower one, for this shows that after allowing for the growth in vehicles and population there is a general fall in the accidents in most countries. This is another sign that the population is gradually adjusting its roads and its behaviour to the problems of motor traffic.

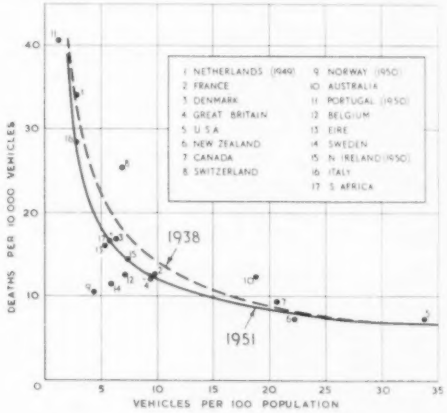

FIGURE 4. *Relation between number of deaths per 10,000 registered vehicles and number of vehicles per 100 population in 1951*

On the basis of the curve in Figure 3 it is possible to make another prediction of the number of casualties to be expected in the future as the number of vehicles grows in this country. The increase would be expected to be about 40 per cent, that is casualties would reach 320,000 in ten years' time.

Table III compares conditions in 1931 with those in 1951 and shows the changes in the number of vehicles and in the fatality rate per vehicle registered. All countries have had very marked increases in the numbers of vehicles, and it is gratifying to note that Great Britain, despite a 97 per cent increase in the number of registered vehicles, had a 22 per cent drop in the number of its road fatalities. Great Britain is the only country from those for which we have data where fatal road accidents have fallen in numbers in the last twenty years. This,

although gratifying, does not mean that much does not remain to be done to reduce the vast toll of road accidents.

TABLE III. PERCENTAGE INCREASES IN NUMBER OF VEHICLES AND FATAL ACCIDENTS BETWEEN 1931 AND 1951

Country	*Percentage increases between 1931 and 1951*	
	Vehicles	*Deaths*
Netherlands (1949)	40	29
France	79	9
Denmark	87	108
Great Britain	97	-22
U.S.A.	100	11
New Zealand	108	84
Finland	117	*
Sweden	127	*
Canada	138	102
Switzerland	146	102
Norway (1950)	149	20
Australia...	162	110
Portugal (1950)	162	*
Belgium	171	100
Eire	172	39
Northern Ireland (1950)	180	26
Italy	230	77
South Africa	257	*
Spain (1950)	*	43

* Not known.

ACCIDENTS AND SOME OF THE WIDER ISSUES

Up to this point I have spoken of the evil of road accidents, of the magnitude of the problem and of possible future trends in traffic and accidents. This is one side of a wider question, for the economic and social life of the country closely depends upon efficient transport and therefore largely upon having efficient roads. A high standard of living is inextricably bound up with a high standard of road development. In this country over 1½ million people are employed in connection with road transport and therefore directly depend upon it for their livelihood, and the expenditure on road transport is over 10 per cent of the national income. In the United States one worker in seven is said to be employed in some phase of highway transportation. Moreover the ordinary man puts a high value on individual transport by motor car.

Thus, although in addition to the human suffering caused the economic loss to the country arising from road accidents has been estimated at as large a figure as £100 millions or more a year, it is difficult to see how we can, in a highly competitive world, adopt a policy of reducing accidents whatever the cost, regardless of the other economic and social consequences. If values could be put to all the accident-producing circumstances and these could be linked on the one side to a full knowledge of the laws of traffic movement in relation to road design, vehicle design, speed and human behaviour, and on the other to full and detailed economic and social assessments, the problem would no longer exist in its present form. The problem would then be to choose the most acceptable balance between known effects.

Such a complete knowledge of the problem is, and always will be, unattainable and it will always be necessary to make decisions on incomplete evidence. But we can and must try by the careful study of accident-producing circumstances and of the effect of counter-measures to make our knowledge more complete than it is at present. This is our aim in road research. The two sides of the question are constantly in mind in the planning and conduct of the research.

However our present concern is not mainly with research but with the wider issues and what we can do about them. Despite the lack of precision in our knowledge and the urgent need for more study the main outlines of the problem are clear and have been clear for many years. There are really only two main sides to the question, on the one hand the equipment we use—our roads and our vehicles—and on the other hand ourselves—the human element.

THE EQUIPMENT: (1) THE ROAD

The days are past when any one of us would argue that our roads are anything but totally inadequate for the traffic they carry. They turn and twist; they vary in width; they mix all types of traffic, and, although many miles have been planned, not one mile has been built with a special eye to the needs of the motor vehicle. It is unnecessary for me to say more, for it is now frankly admitted that they are out of keeping with the age of the motor vehicle, and that what is needed to put things right is a wholesale reconstruction—new roads and improvements to existing roads on a vast scale involving great expenditure.

We spend less than £100 million a year, which is about ½d. a vehicle-mile, on maintaining the roads for our vehicles whereas we spend a total of sixpence or more a mile in the running of our vehicles: if 500,000 new vehicles come on to our roads this year we shall have spent a total of not less than £250 million on new vehicles alone.

It is, so far as road expenditure is concerned, as I have said on an earlier occasion, a matter of outlook and habit as indeed is most spending above the subsistence level. The public attitude towards the road problem is such that road reconstruction is not given high priority in relation to other matters: the provision of cigarettes, beer and television, to say nothing of the social services, are put first. Of recent years much thought and publicity has been given to this question by industrialists and others interested in good roads and

it is clear from recent announcements in Parliament and in the Press that a more favourable atmosphere for road construction is developing. But until the public attitude towards the road problem changes very much more than it has done up to the present we can, of course, do little more than tinker with the question.

In the meantime, we can try to come to grips with our problem by increasing our understanding of it so that we shall know how best to spend the little we now devote to the matter, and we can prepare wisely for the far greater amount that will have to be spent in the future.

In my last Cantor Lectures I gave many examples of the problems tackled by the Department of Scientific and Industrial Research in co-operation with other interested bodies and of the results obtained. The examples of road investigations ranged from studies of town congestion to junctions on rural highways and it is unnecessary for me to repeat the story. We know much more than we did then about the effect on accidents and on traffic flow of the segregation of traffic, of road layout, of pedestrian crossings and pedestrian control. Accounts of this work have been published in the Annual Reports of the Road Research Board and elsewhere.

The study of conditions in built-up areas is particularly important because about three-quarters of the accidents occur in them and because the greatest congestion of traffic is also there. Not only is the accident rate higher in the main streets of Central London but it is nearly four times as high per vehicle-mile travelled as it is on the rural roads of Buckinghamshire. Given the money there is much that can be done to reduce accidents in built-up areas: greater segregation of pedestrian traffic by guard rails and by other means, improvement of surfacings, better street lighting and better control of parking are some of the measures that are urgently needed. A careful study of all black spots by experts would, I think, reveal many things that could be done, often at comparatively little expense.

The problem of developing the main arteries of the country is no less pressing. Much can be done by building by-passes to towns and by widening existing trunk roads. But these can only be palliatives. The final solution must surely rest in special-purpose highways. As long ago as 1938 the Alness Committee, the Select Committee set up to report on road accidents, recommended that one experimental motorway should be built. Since that time we have had none in this country but many have been built by other countries. Germany with its extensive motor road system built by Hitler is busy building more and our continental neighbours in France, Holland, Belgium, Sweden, Portugal and Italy all have examples. America has many. There is no doubt about the saving in time that these make possible—in Germany it is reported that heavy transport can travel up to 400 miles in a working day without difficulty. The saving in accidents is not always so clear, for without adequate controls higher speeds may bring new risks. However, that motorways can be life-saving is proved quite apart from the help that is given to the more congested areas by removing traffic from them. First-hand experience of motorways, in design, construction

and operation, would be of great value in Great Britain, and is an urgent requirement.

Although motor roads would not solve our road safety problem they could make a useful contribution. It is of interest to see what reduction in accidents might be expected from them.

The accident rate on existing roads ranges from 13 per million vehicle-miles to two. Experience abroad shows that on a motor road built to the best possible standards the rate might be as low as 0·6, the value recorded for the Davison Expressway in Detroit. The reduction could, therefore, range from about 12·4 to 1·4 per million vehicle-miles, according to the conditions that are being relieved.

For a motor road carrying 20,000 vehicles a day for 250 days a year the economic gain to the nation from the reduction in accidents would be 15 per cent per annum for a saving of 12·4, and 2 per cent for a saving of 1·4 accidents on a capital outlay of £200,000 per mile of road. These figures would, of course, all be much less if the traffic carried were less. But as motor roads are required mainly for busy routes and rapidly attract traffic to them they are perhaps not unreasonable ones. They would be additional to the other and more substantial economic returns from busy motor roads. The 1946 plan for motorways visualized the construction of 1,000 miles of them. This length of busy motorways, could, therefore save over 7,000 casualties per annum at the lower rate and possibly many times that number.

Before leaving this brief discussion of the road element in road safety I should like to say a word about what may at first sight appear to be a comparatively minor matter, the road surface. I do not think it is. For with the modern, faster motor vehicle this subject is assuming a much greater importance than it has had for many years past, and former standards are not good enough. It has become clear that the rough-looking surface is not always as good as it appears to be, for some kinds of stone tend to polish more than others. In one recent example, following a general improvement in road alignment and the application of what is known as an open-textured carpet, eight accidents were reported in four months whereas there had been none in the previous year. Tests were made: it was found that the surface had a low resistance to skidding. After treating the surface with a better material no further accidents occurred in the following six months. Similar treatment on a slippery but rough-looking surface at a roundabout reduced accidents from 33 to seven a year. The estimated saving in the cost of accidents was £3,000 to £4,000 in one year and the cost of the treatment was £150. Similar but not quite such spectacular results were obtained by roughening the stone setts in a busy city street. This way of reducing accidents must rank among the least costly and most certain of the methods that can be employed. Compared with the expected reduction of ten fatalities a year, from a capital expenditure of £17½ million and an annual expenditure of £2·2 million on an improved railway signalling system, the cost is negligible. On that basis, on an equal valuation of expenditure justified in order to save life, to save the same percentage of the fatalities occurring in road accidents, the

justifiable expenditure would be over £2,000 million in capital and £300 million annually.

THE EQUIPMENT: (II) THE VEHICLE

We shall later consider some of the ways in which the human failings of drivers contribute to road accidents. One way of reducing the effects of the human element would be to design and maintain vehicles so that they make the minimum demands on the driver. For safety on the road the driver must be able to see clearly where he is going, to stop quickly if the need arises and to steer where he wishes. This is, of course, quite obvious, but the fact remains that an examination of vehicles reveals features which conflict with these simple fundamental requirements, and which show that a high proportion of vehicles in use are in poor condition.

In my earlier Cantor Lectures I had a good deal to say about these matters and particularly about dazzle from headlights and about brakes and skidding. Since then the studies have been pursued further.

The pedal cycle

We have seen that the pedal-cyclist is one of the more vulnerable of road users, and for this reason alone the condition of his machine is of great importance to him. From examination of children's bicycles it has been found that through neglect of proper maintenance some 40 per cent are faulty. There can be no doubt that the 'immediate action'—the training and the licensing of the child cyclist—called for by Professor J. Harry Jones in a recent letter to *The Times* is of great importance. It would be still more effective if this were linked to a scheme for maintaining bicycles in proper condition.

The motorized bicycle presents special problems because generally the brakes and lighting are those of an ordinary bicycle. This subject is receiving careful attention at the present time.

Dazzle

All drivers who use the roads at night are aware that the state of vehicle headlights leaves much to be desired. This is because lamps are of many different designs; a high proportion are badly aimed and many have deteriorated to a feeble glimmer or are completely out of focus. Measurements showed that about 40 per cent of the meeting beams (i.e. dipped headlights or passlights) are more dazzling than they were designed to be.

Facts about the mis-aim and deterioration of headlamps were obtained in a survey of about 800 vehicles on a trunk road near Oxford. Only about one in ten of the lamps were set with approximately the correct aim, whilst about half were displaced more than 3° from the correct setting or were in such a poor condition that it was impossible to estimate their aim with any degree of accuracy; 3° is approximately the angle between the main and dipped beam of an ordinary dipping headlamp. Of the passlamps about one-quarter were aimed above the horizontal. Fixed headlamps on some of the older cars and on commercial vehicles showed the same faults.

While mis-aim can give rise to very high or very low intensities deterioration always gives rise to low ones. It was found that one car in six using the dip-and-switch method (mostly the older cars) had a maximum intensity of less than one-tenth of what it once had, and one in two was below one-half. These surveys have shown that mis-aim and deterioration are so prevalent that it is not surprising that there is complaint about dazzle on the roads. For when the users of poor lights meet a vehicle with lamps in good condition, they are badly dazzled. But unless they have driven with good lights they may not realize how much they themselves contribute towards this result. Even when the road is clear of other traffic, these poor lamps give a reduced range of vision and may contribute to an accident.

The International Commission on Illumination has been engaged for some time past in an attempt to decide upon a standard headlamp which will prove acceptable in all countries. The Road Research Laboratory is collaborating in this work. The general conclusion from the work of the Road Research Laboratory at present is that, whilst it is necessary to choose a good design of headlight beam, there is quite a range of designs any one of which if generally adopted would give very similar visibility. What is absolutely essential after standardizing one of these designs is to get a real uniformity by seeing that the lamps are correctly aimed and maintained. Unless this is achieved hope of improvement will prove illusory. Periodical testing and enforcement of standards by the police will, I think, prove essential if a high standard is to be maintained.

Brakes

With the co-operation of the police the brakes of vehicles in use on the road have been tested. Good brakes can stop a car in 45 ft. from 30 m.p.h. About half the cars tested required about 70 ft., one in ten over 100 ft. and one in a hundred over 200 ft.; and these figures do not allow for the reaction time of the driver. Some of the heavier commercial vehicles also had very poor brakes, owing to the slow build-up in the braking system. Only about 10 per cent of the brakes on the front wheel of motor-cycles were efficient. In other tests one in four cars had very little braking on one or more wheels.

Rearlights

A survey made during the winter of 1950-51 of the intensity of rearlights on vehicles in use showed that three-quarters of the private cars, commercial vehicles and motor-cycles, and 98 per cent of the pedal cycles had rearlights with intensities lower than that required to make the rearlight plainly visible when seen near the dipped headlights of an oncoming car. Four in five pedal cycles and three in five of the commercial vehicles had rearlights of less than one-tenth of this brightness. The inadequacy of rearlights as a factor in night-time accidents was revealed by a statistical analysis of night accidents. This showed that inadequate rearlights were probably the cause of about 3,400 casualties a year (about 9 per

cent of all night casualties); the resulting monetary loss to the community was estimated to be about £2 million a year. Since 1951, when these results were first published, there has been some improvement in the standard of rearlights, especially on commercial vehicles, and in view of the new standards now required by the recent legislation still greater improvement is to be expected. The rear-lighting of pedal cycles still remains a particularly serious problem, not yet dealt with by official regulations. Highly efficient rearlights can now be obtained at a reasonable price but designs of dangerously inferior quality continue to be sold to the public.

Vehicle inspection

It is clear from the foregoing that the condition of many vehicles in use on the roads is very unsatisfactory. Brakes and lights of many are inefficient, some grossly so. How can we ensure that vehicles are used in at least a reasonably roadworthy condition?

Improvements enforced by allowing only equipment of approved types to be sold might have a considerable effect, but to be certain that the initial standard was maintained further measures would be necessary. In its 1947 report the Road Safety Committee of the Ministry of Transport recommended that vehicle-testing stations following the American pattern should be set up in this country. In some States in America the law requires that all vehicles shall be inspected periodically, usually once or twice a year. The brakes are tested on special machines, the intensity and aim of headlamps are checked, the steering system is examined and all the accessories having a bearing on safety are checked to see that they work efficiently. A deficiency in any respect has to be put right by the vehicle owner. It is significant that the accident rate per million vehicle-miles in the States having vehicle inspection is, on the average, about 20 per cent lower than in States without inspection.

Let us look at the economics of this question. Vehicle inspection in America costs about ten shillings per vehicle per annum. Added to this is, of course, the cost of taking the vehicle to and from the testing station. But if testing were done by approved garages at times to suit the individual this would be low. Assuming that we can disregard this addition and can apply the American figures to Britain we might expect that inspection of all British vehicles would cost £2½ million and would hold out the hope of eliminating 20 per cent of all accidents and therefore of saving some £20 million. The introduction of vehicle inspection is therefore at the least a very attractive speculation in safety with the possibility of large dividends. Looked at from the point of view of driving comfort alone, and setting aside all considerations of safety, it is quite certain that, with proper regulations on uniform headlights, dazzle from improperly adjusted or deteriorated headlights would be very greatly reduced. As motorists ourselves, many of us would willingly pay ten shillings a year to ensure that the headlights of all other motorists were properly adjusted!

OURSELVES—THE HUMAN ELEMENT

Let us now look at the other main side of the question—ourselves, the human element. This is just as important as, perhaps more important than, the equipment we use. Here we are concerned with how we behave as road users, with our fitness as drivers, with training and propaganda, with courtesy and with discipline and how far we should sacrifice individual freedom in the cause of road safety.

In this field there are great gaps in our knowledge; in fact, progress is only beginning. It is indeed difficult to say anything which is based on substantial fact as against reasonable opinion. This was even shown in the recent debate in the House of Lords on speed limits, when, if I may say so, opinions were dispensed with eloquence but with a singular lack of reliable supporting facts.

The truth is that many of the road safety measures adopted in the past have not been applied in such a manner as to make a factual assessment possible. This is certainly the case with most road safety propaganda. Although most of us feel that there has been some resulting beneficial effect, it has not usually been planned and carried out in such a way that the effect can be measured. A plan for measuring the effect of any substantial change, whether physical or administrative, should, in my opinion, be coupled with each scheme: a proportion of the funds and the effort should be set aside specifically for this purpose. A corollary to this is that only those propaganda schemes which are judged to have some reasonable chance of producing measurable effects should be adopted.

When road safety propaganda was being discussed some years ago, a member of the Road Research Board proposed that a medium-sized town should be selected for a comprehensive experiment and demonstration on road safety. The suggestion was that everything possible should be done to make the existing roads of the town safe. It would then, by acting as a practical example of what can be achieved, set the pace for other towns and perhaps for the whole country. The proposal was deferred for a variety of reasons. It has been raised again within recent months. It might not prove to be very costly. It would, I think, be a very interesting, useful and highly profitable experiment to make.

The pedestrian

There are some interesting trends in pedestrian accidents shown in Figures 5 and 6. Driver and passenger casualties are also shown in the figures, which deal respectively with British and American conditions. The most notable features are the fall since 1938 of pedestrian casualties and the general increase in driver and passenger casualties. The increased speed and volume of traffic particularly in non-built-up areas may account for the upward trend of the driver and passenger casualties. The decrease in pedestrian casualties may be due to a greater awareness of danger, or to a reduction in the numbers of pedestrians exposed to risk arising for example from the greater use of motor vehicles in carrying people to their jobs and children to school. These questions need closer study.

Getting the pedestrian safely across the road, however, still remains one of the major problems of road safety concerning the human element. The zebra crossing was one of the examples of a planned investigation of human behaviour that I was able to give in my earlier Cantor lectures. The crossing was then at the trial stage and I could not then give any indication as to the effect on accidents. This is now possible. An examination of available statistics shows that: (1) pedestrian accidents fell more than non-pedestrian accidents; there was a 7 per cent decrease in pedestrian accidents; (2) accidents fell more in towns than in rural districts, 8 per cent compared with 2 per cent; (3) accidents went up by 2 per cent in Northern Ireland both in towns and in rural districts—there were no changes in regulations in Northern Ireland; (4) accidents went down more in towns with pedestrian crossings than in towns without them; (5) although pedestrian casualties have increased in 1953, compared with 1952, they are still less than those in 1951. On the other hand, the number of non-pedestrian casualties is greater than in 1951 and 1952.

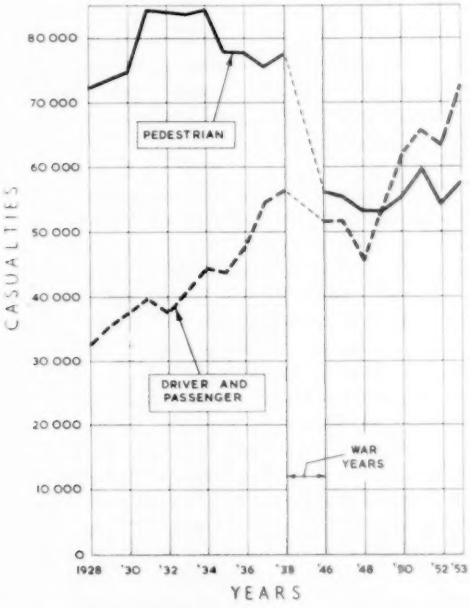

FIGURE 5. *Pedestrian and non-pedestrian casualties, 1928–1953*

The zebra crossing has helped, although it has not solved, the problem of getting the pedestrian safely across the road; nor can we expect any system to do so which does not provide for a more definite separation of the streams of

pedestrian and vehicular traffic. Separation by providing traffic lights has been shown to halve pedestrian accidents, but separation by tunnels or bridges is not always so effective because, without compulsion, pedestrians will not use them if the time taken to cross the road when using them is appreciably greater than the time taken to cross in the normal way.

The question of pedestrian discipline is one that has received a good deal of attention in some countries. The best methods of achieving it merit careful consideration.

Accident-proneness

It is generally accepted that even if motor vehicles and roads were vastly improved some road accidents would still occur because human beings are often careless, foolish and inconsiderate. It seems reasonable to suppose that, as some people are worse at games and crafts than others, some people will be worse drivers than others and much more liable to make mistakes and be involved in accidents. If such drivers could be detected and prevented from driving or given special training then the road accident rate would fall. The basic assumption underlying such a point of view is that an individual's susceptibility to accident is fairly stable but that individuals differ one from another even under the same conditions.

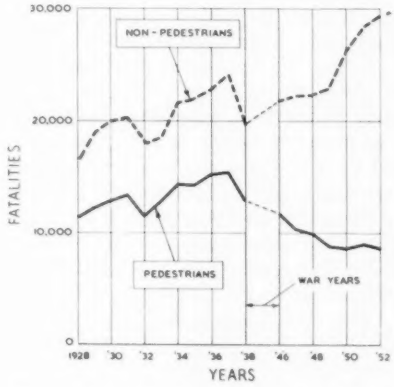

FIGURE 6. *Pedestrian and non-pedestrian fatalities in the United States, 1928–1952*

If, for example, we consider the accidents sustained by the drivers in a particular city, on this hypothesis we suppose that an individual driver's accidents depend upon (1) his environment, that is the type of vehicle he drives and the character of traffic encountered, (2) the driver's inherent accident-proneness, and (3) the operation of the laws of chance which will tend to mask the operation of (1) and (2). Thus, a driver with a large number of accidents may be accident-prone, or he may have driven a great mileage, or he may have been merely

unlucky, or alternatively a combination of all three factors may be responsible.

Such evidence as there is seems to show that accidents are not distributed by pure chance but that the divergence from the laws of chance is not sufficiently great to enable individual accident-proneness to be detected with any degree of certainty solely by a consideration of drivers' accident records. If, however, by various physical and psychological tests some disability or defect is found which is common among the accident repeaters but uncommon among the accident-free, then such a test, in conjunction with accident records, could be used to diagnose cases of accident-proneness.

Unfortunately, no simple defect has yet been discovered which is common to accident repeaters but not to the accident-free. The high accident group have roughly the same blood pressure, the same reaction time, the same intelligence as the accident-free group. However, one rather important fact has emerged from this type of investigation. It is common knowledge that people are best at physical and psychological tests in their early twenties, and as they get older their scores fall. But it has been shown in many investigations that the 40- to 50-year-old driver has fewer accidents than the 20 to 30 age group. Drivers are apparently safer at an age when their scores on tests are low and are dangerous when their scores are high.

Something other than pure skill or physical fitness must therefore be of great importance in determining accident-liability. It may, of course, be simply that the increasing experience reduces accident-susceptibility, but recent work suggests that the missing factor is connected with what psychologists call temperament. Temperament changes with age and its increased responsibilities; this factor may account for the reduced accident-proneness of older people. Both in this country and in America investigations have shown that the bad citizen is likely to be the bad driver. For example, in a study of two groups of taxi drivers in London, Ontario, it was found that the accident-free group had a good school record and parental history, several hobbies, few absences without leave, but the accident-repeater group was inferior in each respect. In an examination of truck drivers another investigator found that drivers involved in preventable accidents tended to be free of tension and worry, independent, cocky, aggressive and domineering. A War Office investigation showed that Army drivers who were involved in accidents frequently had a history of military indiscipline and in civilian life changed jobs frequently. It is surprising that such obvious advantages as short reaction time and high intelligence do not appear to play a very important part in accident-proneness. There may be a simple explanation; gross deficiencies may be rare among drivers or a driver may be well aware of his defect and be able to compensate for it. He may not be at all aware of a temperament predisposing him to accidents.

It is clear that in the present state of knowledge we have no reliable way of recognizing the bad driver. This might be obtained by a more intensive investigation than has yet been undertaken, by maintaining an index—perhaps on a sample basis—of drivers involved in accidents and linking this to observations and tests on a representative selection from them. It has been argued that this,

and the application of the lessons learnt, would involve inroads on the liberty of the subject: moreover, that the results could not be applied because some safe drivers would always suffer with the unsafe. Ignorance is not bliss where road safety is concerned and I think we should, despite the contra-arguments, try to fill the gaps in our knowledge.

Driver training

In America driver instruction is given as part of the regular curriculum in High Schools. In 1952 at least 6,000 schools offered complete courses including road training; they were taken by about a third of a million students. The total cost of this training is about £3,500,000. Does such training lead to fewer accidents? Several studies have been made by comparing the accident experience of a group of trained drivers with a similar-sized group of untrained drivers.

Table IV summarizes the results from twelve studies in states and cities in America in which the accident rates for men and women were separately evaluated. It will be seen that the trained drivers, both male and female, had a much better accident record than the untrained.

TABLE IV. THE RATIO OF THE ACCIDENT RATES OF UNTRAINED TO TRAINED DRIVERS IN COMPARABLE PERIODS OF TIME (U.S.A.)*

	Exposure in driver-months	*Accidents*	*Accident rate per 1,000 drivers per month*	*Ratio of accident rates: Untrained Trained*
Men and boys:				
Untrained ...	123,865	979	7·9	1·8
Trained	61,818	265	4·3	
Women and girls:				
Untrained ...	42,581	110	2·6	2·2
Trained	62,272	72	1·2	

* Original data from the American Automobile Association Research Report No. 39, July, 1953.

Another example of the great advantage to be obtained from good training was shown by an investigation made at the Road Research Laboratory into the accidents experienced by about twenty groups of drivers from transport undertakings, government departments and the police. It was found that the police training school record was the best by a large margin: they had only half the number of accidents of the best of the others and the worst had over ten times the number.

Amongst the licensed drivers in this country one in twenty will have had his first licence during the past twelve months and therefore will have had less than one year's driving experience after having passed his test.

I have already referred to the need for training the child cyclist. Hardly less urgent is the training of the motor-cyclist, who contributes so heavily to the toll of the road. The Royal Automobile Club and the Auto-Cycle Union, strongly supported by the Royal Society for the Prevention of Accidents, already have a training scheme for motor-cyclists in operation, but at present it can only deal with small numbers. Here is a good foundation on which to build.

One of my colleagues at the Road Research Laboratory, Mr. G. Grime, when holding a Commonwealth Fellowship in 1952 in the United States of America made a careful study of the accident rates of American long-distance motor transport concerns. He examined the methods of selection, training, supervision, discipline and rewards. Some of the records showed exceptionally low accident rates which he attributed to the following:

(1) The high standard of professional driving set up by safety supervisors and accepted by drivers. The professional driver is expected to use 'defensive driving', so that no matter what the other road user does no accident will take place. He is judged to be at fault if he neglected to take any possible precaution to avoid the accident, or failed to anticipate the possible actions of other road users. By these severe standards accidents are judged to be either 'preventable' or 'non-preventable', and for all preventable accidents the driver is held to blame.

(2) The system of supervising drivers on the road by means of patrol cars.

(3) The high rewards for safe driving, in the form of high wages, bonuses, and prestige, and

(4) The severe penalties for having preventable accidents.

The considerable savings effected were said in some cases to have made the difference between profit and loss.

Drunkenness

How far is drunkenness a cause of road accidents? Unfortunately, this question cannot be answered with any certainty. Police records show that under 1 per cent of the road casualties in Britain are classified as due to drink; this figure is almost certainly an underestimate, possibly a gross underestimate. Consider for a moment the problems confronting a policeman who finds a driver whom he suspects of being under the influence of drink. In order to bring a satisfactory case medical evidence has to be produced, so the driver has therefore to be taken to a police station and to be examined by a police surgeon. The driver can, if he wishes, call his own doctor. As all this may be in the middle of the night and there may be delay, in all probability the suspected person will rapidly become sober although, at the moment he was first seen, he might have been quite incapable of driving.

The difficulties in securing the conviction of persons manifestly under the influence of drink or drugs have been dealt with in some of the Scandinavian countries by re-defining the criteria for drunkenness. Instead of relying on behaviour tests a person is considered unfit to drive if the alcohol content of his blood, measured by chemical means, is above 0·1 per cent in Denmark, 0·05 per cent in Norway, and 0·15 per cent in Sweden. In some American States also the limit is 0·15 per cent and breath tests are used instead of blood tests. In this country research is being carried out by the Medical Research Council at the Road Research Laboratory on the effect of small amounts of alcohol on a person's ability to perform a task similar to driving a car.

The whole question of the detection of drivers who are under the influence of drink may eventually have to be reconsidered in the light of this investigation and of the success or otherwise of the new legislation in use in other countries.

Speed

There are conflicting views on the subject of speed. Some people believe that speed is the cause of all accidents; they begin with the argument that if all vehicles were stationary there would be no accidents. Others think that it is the cause of none: this attitude is illustrated by some of the arguments advanced in the recent House of Lords debate on speed limits, for instance, "That speed, *in itself*, is no danger factor at all". The fact is that although there is an obvious measure of truth in both these arguments they both beg the question: for in the first case if we are to use vehicles at all we must have some speed and in the second case speed cannot exist by itself, separately from the attendant circumstances.

The speed of a vehicle affects many things that have a direct bearing on accident potential. For as speed increases the vehicle travels further before the driver can begin to act on his impressions, the forces resisting skidding are less, the distances at which objects can be seen at night decrease, and the brakes take longer to bring the vehicle to rest. Moreover, the energy stored up in the vehicle increases as the square of the speed, and hence the seriousness of any accident increases rapidly with speed.

The driver is constantly faced with the problem of deciding his speed. In doing this he continually weighs up the situation: can he overtake before an approaching vehicle reaches the one he wishes to pass; can he, in view of the condition of the road, take the bend he is approaching without slowing down; when should he begin to apply his brakes so as to stop at the cross roads ahead, and so on. If he is skilled, experienced and a safe driver, his decisions are sound, if he is not so skilled his judgments must be less reliable, or if he is prepared to take risks his safety margin will be less. The effects of a burst tyre or a failure of the brakes or of the steering mechanism will, of course, be more serious the higher the speed.

It seems, therefore, hardly to be questioned, other things remaining the same, that higher speeds mean greater danger and accidents of greater severity. What statistical evidence is there to support this conclusion?

First of all we must discard as unacceptable the evidence of the police statistics that only a few per cent of accidents have speed as a contributory factor. Judging the speed after the event is much too uncertain a procedure. Secondly, the 1934 Road Traffic Act, which came into force in 1935 and which established the 30 m.p.h. speed limit in built-up areas, was followed by a substantial reduction in the number of accidents and by a much greater reduction in their severity. Whether this effect continued for many years is not, however, certain. Thirdly, in 1953 the ratio of fatal to all casualties in built-up areas subject to a 30 m.p.h. limit was 1·8 per cent and in non-built-up areas 3·3 per cent. Finally, speed limits have been imposed on motor roads in America and in Germany with, it is reported, beneficial effects. On the Pennsylvania Turnpike, a motor road of fairly modern design, with dual carriageways, speed limits have recently been fixed at 60 m.p.h. for private cars and 45 m.p.h. for commercial vehicles.

Shall we in Great Britain eventually come to the conclusion that speed limits for non-built-up areas are desirable? That speed limits can be irksome, particularly when roads are deserted, cannot be denied. I think the answer will be, yes, for it would seem certain that lower speed means fewer and less serious accidents even though there may be some drivers whose judgement, experience and temperament are such that they can drive fast where circumstances permit it, without greatly increasing their chance of an accident.

The question of enforcing speed limits is of course very important. This depends not only on the effort the police are willing and able to give to it but also on the reasonableness of the limits in relation to local conditions. There seems little doubt that the time is ripe for the general question of speed limits—their location, the speeds to be permitted and their enforcement—to be reviewed.

I do not think the public is yet fully aware of the great benefits that come from proper police activity in road safety. The 'courtesy cop' was a very profitable investment. Promoting road safety should not, in my view, be considered as one of the less important of the police duties. The rewards in benefit to the nation are as great as or perhaps greater than in any other field of police activity.

SOME CONCLUDING OBSERVATIONS

Reviewing the subject generally it is clear that the motor vehicle has caught the world by surprise. In fifty years it has completely transformed our whole economy and mode of life. It has come as a flood and our flood defences have been overtopped long before we have finished building them. Have we caught up even in our thinking? I think not, and yet this is surely the first step towards a rational development of our road system. Road accidents constitute a moral problem of first importance both to the individual and to the community.

We have seen that, apart from wars, major catastrophes, and active administrative measures, accidents tend to fall gradually in relation to the traffic growth in most of the countries of the world—a process of evolution: in fact, the tendency to fall is greater in Great Britain than in other countries. Nevertheless, they grow

in numbers because traffic grows so fast. We are, therefore, forced to the conclusion that big changes are essential to produce big effects.

What could these big changes be?

Our tasks are clear: first to see that our equipment—our roads and vehicles—is in first-class condition. Secondly to see that we each understand our responsibilities and that we are properly fitted and trained to undertake them; and, thirdly, to see that sanctions are properly devised and applied to maintain the necessary discipline.

We have seen that in all three respects it is not merely a question of eliminating slight imperfections: the imperfections are gross ones and to put them right within a measurable period would mean heavy and continued expenditure. In particular the major items such as the building of motorways, expressways, ring roads, overpasses and underpasses would be expensive. They are, however, essential elements in the adjustment of our civilization to the motor vehicle and the sooner a start can be made with them the greater the benefit that will be felt. Big changes may also consist of many small changes applied in such a way as to build up into a big wave of awareness and activity. In the course of my lecture I have named some big changes and a number of smaller ones that would help. But the biggest change of all, and the most essential one, is a change of outlook on the part of ourselves. A new sense of personal responsibility, of personal discipline, of unselfishness and of service and courtesy one to another is required.

I cannot end my lecture in any better way than by quoting the words used by the Lord Bishop of Carlisle in the recent debate in the House of Lords, which I think strike at the root of the human side of the problem.

'Bad driving or dangerous driving is social immorality, and a civilized society must see that such actions receive the censure they deserve. I believe that, in the eyes of Christian men, bad driving is a sin against God's creatures—a sin which daily adds to the suffering, the sorrow and the bereavement of the world.'

Acknowledgement

I wish to place on record the ready help I have received from my colleagues of the Road Research Organization in the preparation of this lecture, and particularly from Miss G. O. Jeffcoate, who undertook the task of assembling and checking the many statistics which I have quoted.

II. SAFETY IN THE AIR

by

AIR COMMODORE SIR VERNON BROWN, C.B., O.B.E. (Retd.)

Late Chief Inspector of Accidents, Ministry of Civil Aviation

Monday, 1st March, 1954

From the earliest times man has been able to move from place to place by means of ships and land transport. But he has always longed to fly. He has tried to emulate the birds of the air, the gods, the angels and the demons. And even in the sphere of mythology there seem to have been accidents. To remind you of one of the earliest I mention the story of Dædalus and Icarus. Further down the ages we hear of King Bladud, who was supposed to have lived in about the eighth century A.D. and to have been the father of Shakespeare's mythical King Lear. He was said to have lived at Bath, and there is a little verse about him as follows:

Bathe was by Bladud to perfection brought,
By necromantic arts to fly he sought,
As from a tower he thought to scale the sky
He brake his neck because he soared too high.

The theory of flight seems to have been tackled scientifically for the first time in the fifteenth century, when the great Leonardo da Vinci made careful studies of bird flight. We know that he attempted to build a kind of glider which, in an excess of zeal, his assistant broke for him—as well as his own leg.

At the end of the nineteenth century some degree of success in soaring flight was achieved by Lilienthal, Pilcher, Chanute and others, though not without some fatalities, and in 1896 Langley's small power-driven 'Aerodrome' was successfully launched from runners on a house-boat and flew for approximately one minute. But it was not until 1903 that the Wright brothers first made a powered flight in a machine which could carry a man. Thus although the aeroplane was thousands of years behind the ship, it was only about eighty years behind the steam ship and about seventy behind the railway engine, and it only lost to the motor-car by about ten years. In fact, it owed its early power plant to the development of the internal combustion engine.

Now what is the obvious and all-important difference between this latest form of transport and the others? The answer is, of course, that it is three-dimensional. Where safety is concerned this is very important.

Two wars have had a remarkable effect on the rapidity of aircraft development. The necessity of achieving superiority over the enemy in the air by means of the air arm of the fighting forces caused the Government to muster the country's best brains in order to design and build at the greatest possible speed the aircraft, the engines and the mass of essential ancillary equipment, so that we might survive. The Atlantic was not flown until 1919, but a little more

than twenty years later a regular stream of aircraft was flying between Canada and this country. I remember flying to Montreal in the autumn of 1944, and that that particular trip was, even then, our pilot's hundredth crossing.

During the last war the United States went far ahead of us in the development of transport aircraft, so that in 1946 we found ourselves in the position of having to convert our war material for civil use. Moreover, at about that time, apart from the then three Corporations, a great number of small charter companies sprang up. Whatever were the causes it is regrettably true that in the first year or two after the cessation of hostilities there were too many accidents in this country. Such statistics as were available compared very unfavourably with what was going on in the Western Hemisphere, but since then our standards have been tightened up and the flying hours and miles flown have increased enormously. As a result, statistics to-day show far fewer accidents per passenger mile flown by our scheduled and charter companies than ever before.

Now let us consider what are the fundamental qualities necessary in a modern aircraft. It must fly at high speed and carry big loads in any part of the world by day and by night, and fly in almost any weather conditions. Moreover, it must fulfil these requirements with safety, regularity and comfort. I am sure everyone will agree that safety has priority of place, for if the chances are too great that one is likely to arrive at one's destination with a broken limb or not to arrive at all, the fare-paying public will prefer to travel by some other means.

How, then, can safety be achieved?

The following seem to be the most important factors: airworthiness, crashworthiness, airline operation, maintenance and inspection, accident investigation, the passing of information among government departments, designers, manufacturers and operators, statistics, and publicity. I will deal briefly with each of these.

AIRWORTHINESS

This is a term which embraces the many requirements which go towards making an aircraft as safe to fly as possible, having regard to the available knowledge. Broadly speaking, these requirements cover design, construction and performance. The journey from the early military types of the First World War and those civil aircraft which immediately followed to the large modern transport aircraft of to-day is a long one, and the speed at which so much ground has in fact been covered makes one wonder if designers ought not to take a short rest to give their staffs a chance to catch up with them. To design an aircraft requires considerable knowledge of aerodynamics, structures, hydraulics, electrics and pneumatics, and even so, the designer is always dependent on his opposite number in the engine world to provide him with a power plant which will make possible the fulfilment of his dreams.

What does all this involve?

It means that consideration has to be given to overall weight, safety factors, speed, range and pay-load, structure weight, landing gear strength and taxying loads, strength to withstand gust conditions, flap mechanisms, powered controls,

cabin pressurization, ventilation and heating, the performance requirements for take-off, landing and ditching, and the thousand and one pieces of equipment which go to make up the complex whole. To that short but formidable list must be added the power plant and engine accessories, the instruments and radio equipment.

Obviously standards must be set and means provided for ensuring there is no backsliding. It is the Air Registration Board which deals with such matters. This is an organization set up by Parliament to advise and assist the Minister responsible for civil aviation in technical matters. Not only does the Board stipulate the requirements of the Civil Code but it also watches over a civil aircraft from the drawing-board stage until its ultimate passing into service. It is often said that regulations are unnecessary or that in any case there are too many. That is, of course, nonsense. There must be regulations and they must be capable of enforcement. In dealing with so complicated a subject as aviation there is bound to be a lot of them. It simply cannot be avoided. The Board has tried to lay down requirements aimed at a uniform minimum level of airworthiness and I believe it has succeeded and that it is doing a fine job. I am quite sure that our standards compare favourably with those of any country in the world. The evidence of this is reflected in the statistics, which show that accidents due to faulty design or construction are a very low percentage of all causes.

CRASHWORTHINESS

I do not know who coined this word but I think it is a good one. Broadly speaking, it refers to the provision of protection of an aircraft's occupants in a crash. I have already said that the proportion of accidents due to airworthiness defects is small. I believe that short of trying to offer protection in accidents of the collision and flying into mountains kind, there are probably no drastic foreseeable improvements at present.

But a lot can still be done to save people from death or injury in the lesser kind of accident, by which I mean over- and under-shooting, belly landing, ditching and the low speed, survivable kind of crash—perhaps accompanied by fire. Please do not misunderstand me. A great deal has already been done in such respects and crashworthiness problems are being constantly reviewed. For example, *means of preventing fires*, and of detecting and extinguishing them if they unfortunately do occur, are the subject of continuous research and development. But one must not be blind to the fact that a crash which involves the destruction on impact of an aircraft's fuel tanks and releases hundreds or even thousands of gallons of highly inflammable fuel, some of which may be sprayed on to red hot exhausts or jet tail pipes, is a very difficult problem to overcome. But a major fire can only occur if a large quantity of inflammable fuel is released and this can hardly happen unless the fuel tank or tanks are broken. The evaluation of integral and bag tanks is a matter for experts and I can do no more than suggest that whatever kind of tank is used it should be capable of withstanding high impact loads, should not be placed in an unnecessarily vulnerable position and ought to be as far away as possible from

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FIGURE 1

the known sources of ignition. Moreover, it should not have an array of pipelines, pumps and excrescences on the underside where crash impact is most likely to cause damage or total disruption.

Next I must mention the much discussed controversial question of *backward facing seats*. There is ample evidence that in crash landings head injuries are the most frequent causes of death or serious injury. Now the human frame can stand a lot of *g*, and I would like to think that if, say, 20 *g* is sustained the structure of the aeroplane and the safety factor of the seats shall be able to withstand this, because I am pretty sure most people can do so if only they are adequately protected.

Obviously the extent and nature of injury must depend on whether the seat and safety belt remain intact and the extent of damage to the aircraft itself. In a straight crash one's body will be projected into whatever lies ahead and unless seat and belt hold serious injury may result. Even if they do not give way the head and abdomen may suffer. According to Mr. de Haven of the Crash Injury Research Medical College at Cornell University people can survive 40 *g* with only a belt. Nevertheless, the provision of an adequate belt or harness for small children or for people of abnormal shapes and sizes raises a lot of difficult problems, and I am certain that if seats were constructed to withstand at least 20 *g*, and if in addition they faced backwards and were provided with adequate head, back and leg, protection, the mortality figure would, in the case of survivable accidents, be reduced to an almost negligible quantity. I feel very strongly about this and recommend anyone interested in the subject to read Mr. Hardingham's short paper, 'Can chances of survival be increased?' which was printed in the R.Ae.S. Journal in July, 1948.

On January 20th this year a Royal Air Force Valetta crashed shortly after take-off from a service station in the West Country. Figure 1 shows a picture of the wrecked aircraft. Of the five crew members one was killed and three seriously

injured. But of the eight passengers, who included two children aged four and five respectively, five were unhurt and three suffered minor injuries. They were all sitting in backward facing seats.

And now a few words about *ditching*: If it should be necessary to alight in the sea, it is important that an aircraft should float for sufficient time to allow for evacuation of its occupants into boats or dinghies which will give a good chance of survival. Therefore, the aircraft should be a reasonably good 'ditcher', the exits should be adequate and evacuation drill should be explained to everyone and simple to carry out. Life jackets must be easy to put on and inflate, and the life-saving craft should be of a kind to give protection and some degree of warmth and, of course, be equipped with food, water and medical supplies, radio and navigational aids.

Some time ago the Air Registration Board carried out tests to determine the effect of briefing as to the way to put on and inflate life-saving jackets. I am told that the results showed that the time factor alone might mean just the difference between saving and losing lives and produced ample evidence to support my assertion that given the proper equipment and with good team work there should not normally be any drownings, but that passengers must be told where their life-jackets are stowed and shown how to put them on. They should not—I repeat, should not—be left to find out for themselves after an emergency has already arisen.

I submit it is nonsense to say that reference to such matters frightens people. One goes through all this in a ship so why not in an aeroplane where the need is so much greater and where speed of action is so important? I have asked many people for their reactions to a talk on or demonstration of this kind of life-saving drill, and have never yet been told that it made them nervous. On the contrary, many have assured me that it gave them confidence.

Another important item under this heading is *emergency exits*, and these are, of course, just as important for ground as for sea evacuation. An exit is of no use if it cannot easily be opened, if it is too small for a passenger of abnormal build to use, and if on getting out of it one has to drop 20 feet—or even 10 feet—on to hard ground or into the sea with a good chance of breaking a limb in the former or being lost in the latter case. Moreover, exits must be so constructed that they will not jam owing to fuselage distortion. I suggest too, that it really is time that a standard method of opening were accepted. After all, it is important that any passenger shall be able to open the door in an emergency and perhaps in the dark should no member of the crew be available.

AIRLINE OPERATION

It is very difficult to deal with such a wide subject in a short paragraph, but as I only want to high-light a few particular matters I will try and do so very briefly. To begin with, a company must, of course, obtain permission to operate from the Ministry of Transport and Civil Aviation. It will, naturally, only buy approved aircraft of the kind wanted for its particular purpose. It must have its pilots, its navigators, its engineers and its radio operators as well as

its ground staff, and all those people will be properly qualified as required by regulation. That means that they will have had a good training, be physically fit and in respect of certain crew members have had adequate route experience. Moreover, it is customary in all well-run concerns to carry out check tests from time to time.

Before a flight takes place weather information for the route must be obtained, the aircraft loaded, and its weight and the position of the centre of gravity computed. Where maximum pay-loads are of such obvious importance, this weighing and finding of the centre of gravity are done with a very great degree of accuracy. Finally, the flight plan is prepared, the radio and navigational aids for the route are studied as well as landing facilities at any intended port of call. Those, I think, are the most important points and I would add that should it appear to the Ministry that an operator is not functioning as a responsible organization ought, its permit may be withdrawn. There are very adequate safeguards against the employment of unlicensed aircrew. Moreover, permission to take off is withheld by the airport officials unless the regulations about the filing of a flight plan and other such documents have been met, and from the time of take-off until the moment of landing the advice available to a pilot and the assistance given to him are quite astonishing. The standard of our meteorological services and of the operation officials in the control tower or in the ground controlled approach van is very high indeed, and their devotion to duty deserves a special mention which, now that I am in an entirely unofficial position, I am glad to be able to give.

To anyone who has the time and who has never done so I recommend a visit to London Airport, or indeed to any other airport, and feel sure that the confidence of those who are nervous of air travel will be greatly increased thereby. To see how an aircraft is controlled throughout its journey and then from many miles away led to its destination and in conditions of bad visibility talked down or brought down by one of the many other means available, with or without the remarkable modern lighting facilities, will be a revelation to anyone who is ignorant of these matters.

MAINTENANCE AND INSPECTION

Except for the annual renewal of the certificate of airworthiness a periodical examination of a privately owned aeroplane by a licensed engineer is not mandatory. But approved maintenance schedules must be adhered to in respect of any aircraft plying for hire or reward. This means that they must be properly maintained by qualified engineers. These engineers are examined and licensed by the Air Registration Board on behalf of the Ministry of Transport and Civil Aviation. The Society of Licensed Aircraft Engineers is an organization which takes itself very seriously and which has earned the respect of the whole aeronautical fraternity. It has recently established a system of examinations for membership of a very high standard, and I can say that, for my own part, whenever I travel by air I am happy to know that the aircraft has been looked after by members of the S.L.A.E.

ACCIDENT INVESTIGATION

Without knowing why an accident or incident occurs no steps can be taken to prevent a recurrence. Therefore there should be a careful investigation of every untoward event. It was this accepted view that, as far back as 1920, led to the establishment in this country of an Accident Investigation Branch. It was decided that its head should be directly responsible to nobody below the Minister concerned with civil aviation in order that he might be able to speak without fear or favour. Apart from any inquiries such an organization may carry out for, or advice it may be asked to give to, the Fighting Services, its main function is to investigate civil flying accidents in order to make it possible for the Minister to carry out his responsibilities to Parliament and so to the public.

Compared with a ship or a railway train, an aeroplane is a vehicle of flimsy construction which of necessity contains a lot of inflammable substances, in particular, fuel, lubricating and hydraulic oils. It has many instruments and devices connected with electrics, hydraulics, pneumatics and the like. By our Air Registration Board's performance standards it must be able to take off and land within the length of the runway it is intended to use, and to clear any obstacles within the precincts of that runway as well as any high ground on its route. Moreover, allowance must be made for a baulked take-off, or for engine failure during take-off, especially if safety speed has not been reached when the trouble occurs. With the increase of landing and take-off speeds flying technique has, of course, become more and more complicated. On airfields thousands of feet above sea level and in countries where tropical temperatures are encountered, such regulations are, therefore, of great importance.

The human element

In investigating an accident, it will be understood that the question of pilot fatigue may be significant and that one may have to consider for any particular class of aircraft the possibility of psychological causes associated with cockpit ventilation, noise, vibration, temperature, lack of sleep, alcohol poisoning, colds, domestic worry, etc., any of which may affect the pilot's responses to audible and visible warnings.

Finding the true cause of an accident is often very difficult. Generally it is not enough to say there was an error by someone—or as I read some years ago as the finding in an accident inquiry report, 'What goes up must come down'! One must try to find out why an error was made. It may well be that the students of human engineering can help by finding out the limits to which an individual can be expected to go in an emergency in making use of what the designer has given him. Dr. Ross McFarland of the Harvard School of Public Health suggested recently in a paper entitled *Objectives of Human Engineering* that designers must not assume that the pilot is always at peak efficiency and that they should bear in mind constantly the limitations of the older men so that this group will not be called upon to perform beyond their abilities in handling new aircraft types.

But accidents can be of different kinds. As well as the breakdown of the human element they may be due to weather conditions, to faulty design, to mistakes in construction or to bad maintenance.

Weather

An aircraft may encounter storms, sometimes accompanied by turbulence of a kind to give rise to severe buffeting. It may also meet with conditions of rain, hail, icing, snow or fog. Figure 2 shows damage by hail stones to the nosecap of an aircraft. It may also be struck by lightning. The normal effect of this is that small holes are blown in an extremity such as a wing tip or aileron shroud. This gives a rather frightening picture, but one cannot ignore weather hazards when flight safety is being considered. Let me assure you at once that, although accidents have been caused by loss of control in some of the conditions I have just mentioned, I cannot honestly say I know of a single fatal lightning strike. Glazed ice is rare and early warning of such phenomena is usually given. If fog is such that visibility is reduced to what is below the operator's minima a diversion is always offered or advice given to a pilot to return to base before his 'point of no return' is reached.

By courtesy of British European Airways

FIGURE 2

Material

It might be thought that in the case of a high-speed crash examination of the wreckage cannot possibly produce any evidence of value. In fact, careful and systematic examination frequently yields remarkable results.

Figure 3, for example, shows a hole from which the bits and pieces of an aeroplane were dug from a depth of well over 35 feet, and in Figure 4 can be seen the overheated ball race which caused engine failure and subsequent fire resulting in loss of control and the final crash.

Now, as most of you know, during the failure of a metal structure the material is deformed before it yields and when it does finally yield evidence of that deformation usually remains. Fatigue failure in a propeller blade might be revealed by the deformation arcs built up from the seat of origin. The direction of failure of rivets can also be important and it should be possible from them to determine the direction of movement of the adjacent structure. Although wood is of little importance nowadays it is still sometimes necessary to determine the direction of failure of a particular member; the difference between a tensile and a compression failure in timber can usually be recognized.

It has to be learnt by experience what certain marks on the aircraft surfaces indicate. For instance, the damage which can be caused by a bird striking the leading edge of a wing, or the heavy damage caused to the leading edge of the tailplane as the result of its being struck by a dinghy bottle after the inadvertent release of the life-saving craft, are distinct and can be identified.

If an aeroplane wing breaks up in the air—a very rare occurrence in civil aviation I am glad to say—it is important to know the direction of failure. This may be determined in several ways. Smear marks, for instance, can give

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FIGURE 3

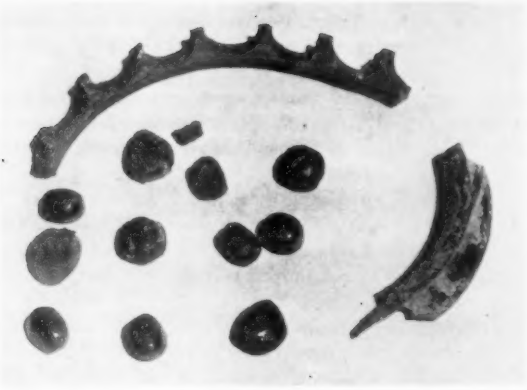

FIGURE 4 [Crown copyright

evidence of a primary or secondary failure. In one case, a mark which extended across both portions of an aileron showed that it was caused when the two surfaces were still mated together and that the surface had been struck by something *before* the break occurred.

From these pictures you will understand the importance of careful wreckage examination—not only on the spot but, if necessary, later under laboratory conditions. That is why the Inspectorate of Aircraft Accidents is so desperately keen that the wreckage of a crashed aeroplane should be left intact until an opportunity has been afforded for expert examination. The removal of pieces of wreckage may well ruin all chances of successfully finding the cause of an accident.

Figure 5 is a good illustration of what I am trying to emphasize. This piece of white plastic material was a portion of the nose of an experimental aircraft which broke up in the air during test. You will see embedded in it a small piece of wood.

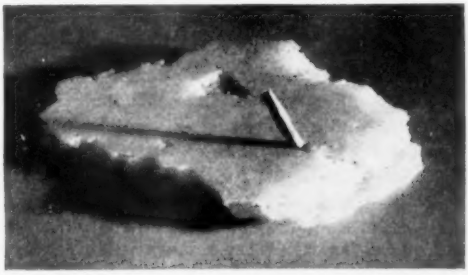

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FIGURE 5

This was only about 4 inches long and was discovered to be a piece of one of the blades of the wooden propeller. The fact that it was embedded in the nose was a strong indication that the propeller had failed before the airframe, and this was subsequently proved to have been the case. This piece of material was found more than three miles away from the main wreckage and it was fortunate that the finder marked the spot and covered the piece over with leaves as a precaution. Sometimes people find parts like this and throw them away, or, what is worse still, take them home as souvenirs.

Careful examination of wreckage can produce valuable evidence. In another case the remains of a control column were discovered, and the fact that the aileron locking pin was fired into its hole in the steel rod when all the outer casing had been destroyed by fire showed that the pilot had taken off with his ailerons locked.

Accidents attributable to bad maintenance are very rare. There have, of course, been some due to this but the majority have fallen into the private-owner class, in which, as I have already said, aircraft need not be maintained by a professional. In one case the flying cable of a home-made sailplane broke and caused a crash. Because its constructor did not know how to make a splice he tied up the end of the cable with a piece of bell wire. Actually, the cause of the cable breaking was his inability to tighten it properly, so that the resulting 'snatch' caused it to fail at the eyelet. The drawing showed that 20 cwt. cable should have been used, but it was found on test that this piece of cable failed at a load of about 4·6 cwt. Further inquiry revealed that it was indeed not 20 cwt. cable, but a length of washing line bought at the local ironmonger's shop.

In the fuel tank of another privately owned aircraft the remains of the chain which had become detached from the tank cap and had become corroded by immersion in the water in the wet petrol, a heap of dirt and the cap retaining clip, which had at some time broken loose and fallen in, were found. Figure 6 also illustrates how bad maintenance caused an accident which unfortunately resulted in the deaths of thirteen people. It is a photograph of the oil pressure filter of one of the engines of this four-engined aircraft. It was so choked up with sludge that it had already begun to collapse. This was not an English aircraft.

THE PASSING OF INFORMATION AMONG GOVERNMENT DEPARTMENTS, DESIGNERS, MANUFACTURERS AND OPERATORS

This is very important. I divide it into two categories: (1) the reporting of every accident and incident, and the passing on of the report even though it may seem to be only of local interest; and, (2) the dissemination of technical information. Under the first of these headings here is a quotation from a recent report by the Flight Safety Division of a certain military command:

> One aircraft, during take-off, required a ground run of over 10,000 feet before becoming airborne on the runway overrun. The take-off distance had been computed as 8,500 feet. The cause of this near accident was the result of the control tower operator erroneously reporting a no-wind condition, when in actuality a 10 knot tail wind existed.

Immediate action was taken to preclude the recurrence of a similar situation.

Once again the incident report became the basis for command-wide preventive measures and to date there has been no repeat performance. In the past, events of this nature went unreported in many cases or, at best, may have been locally corrected.

How often a pilot will talk about some exciting experience but fail to report it officially! He will tell how he made a hard landing but he can seldom be persuaded to write it up. There may, of course, be fears of disciplinary action and there may be prejudices to overcome, but if only some arrangement could be made whereby pilots dropped such reports into a box, unsigned, I am sure some good might result.

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FIGURE 6

In the other category I quote the following by the head of an airline's department of service troubles and research:

> Also occasionally one meets a reluctance on the part of the designer to change a construction which shows malfunctions, even in cases where a solution is easy. I could produce here many examples, but I will restrict myself to one very obvious case. You may know that in order to climb to very great altitudes it is necessary to have the engine provided with a two-speed impellor or blower. During operation this blower has to be changed from low to high by means of a clutch system. Originally this clutch was operated by a cable connection and never gave any trouble. Then this device was changed to an actuator, which resulted in endless trouble. For years we have been advocating the return to the cable which was light and reliable. Now after five years of trouble, the factor is returning to a reliable cable in its newest type.

That illustrates a perhaps natural disinclination on the part of a designer to change a construction which is not entirely satisfactory. But it is even more important that some really vital piece of information obtained by one organization should be made available generally if safety is concerned. It is, of course, easy to understand reticence on the part of a designer or operator where commercial rivalry is concerned, but if people's lives are in danger to keep it 'under one's hat' for purely personal reasons could be an almost criminal act. The war did much good in this respect, for in the common interest at a time of our country's great danger it was agreed that knowledge of this kind should be pooled. And pooled it was. The Ministry of Supply and the Fighting Services, the Ministry of Civil Aviation, the Air Registration Board, the designers and operators still do help one another—and long may this kind of co-operation continue.

STATISTICS

Another important aid to safety is the compilation and analysis of statistics.

But statistics must be accurate and must not be based on numbers which are too small to be realistic. Statistics can be very helpful technically but may be a danger in the hands of those who do not understand them.

Generally, numbers of accidents or numbers of fatalities are related to revenue passenger miles or to revenue aircraft miles. Thus one learns that in the United Kingdom in 1950 the passenger miles flown per passenger killed were 16,198,500, which means that 23,600 miles were flown per passenger killed. If you prefer, you can have it that there were 0·045 fatal accidents per 1,000,000 aircraft miles or that the passengers killed per 100,000,000 passenger miles were 6·2. If you like, it can be shown that the stage flights per fatal accident numbered 61,300. For my part, I think the most realistic picture is that 22,395,000 aircraft miles were flown per fatal accident.

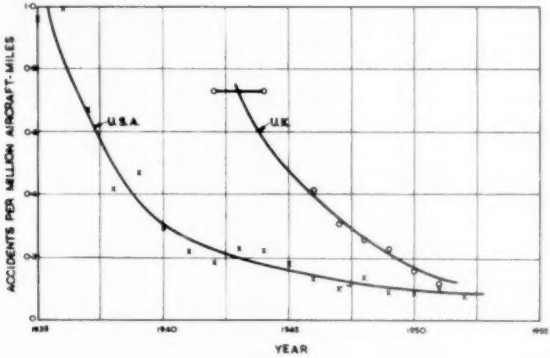

FIGURE 7

According to Mr. Masefield of British European Airways, 'Anyone can be almost 100 per cent safe during the normal span of life—except for acts of God, such as earthquake, lightning, tempest, pestilence, famine and flood—so long as he remains entirely static and earthbound. Equally obviously an element—but only an element—of risk is introduced when he takes the air'. I believe when Mr. Masefield used these words he had in mind that it was said that in the United States in 1947 more people were kicked to death by donkeys than were killed in air transport.

I have tried to obtain some statistical evidence as to which *is* the safest form of transport, but there are so many variables that no comparison seems possible. As to whether it is safer to travel by road, sea, rail or air I can only say your guess is as good as mine. Anyhow, in respect of air travel both in the States as well as in the United Kingdom, Figure 7 gives a picture which I think will give you confidence. It shows the accident rate trend, and I am grateful to Mr. Tye of the Air Registration Board for allowing me to make use of it. You will see that our American friends had about seven years' start of us and that we have taken about ten years to catch up with them.

PUBLICITY

In so far as publicity may serve to keep designers, manufacturers and operators on their toes it can serve a useful purpose, but compared with other forms of transport the aeroplane does often seem to be at a disadvantage. A distorted picture of airline safety is likely to shake public confidence, and I do suggest that the too well-illustrated front page news of an aircraft accident sometimes results in a disservice to aviation generally and to British Civil Aviation in particular.

CONCLUSION

I have spoken about accidents caused by failure of the human element and of those due to weather, defective materials and poor maintenance. I have referred to airworthiness, crashworthiness and to airline operation, statistics and publicity. But you will want to know what is being done to overcome the hazards of flying.

The Ministry of Transport and Civil Aviation has a permanent representative at the International Civil Aviation Organization in Montreal who watches over the United Kingdom's interests in the international field of civil aviation, particularly when standards and recommended practices are discussed. At home it has the help and advice of the Air Registration Board. Arising out of I.C.A.O. representation and the activities of the Air Registration Board and from consideration of accident reports, the Ministry from time to time makes such regulations as seem necessary towards safer flying.

There is a close liaison between the ministries in order that valuable information obtained from the experience of the fighting services and civil aviation shall be pooled, so far, of course, as security makes this possible.This data is made available to the Society of British Aircraft Constructors who can pass it on to the designers and manufacturers. What is perhaps even more important is that the experimental establishments, and particularly the Royal Aircraft Establishment at Farnborough, are available to everybody for advice and guidance. Airworthiness is of a high order and crashworthiness is given its relative importance, and in respect of our pilots, our crew and our ground staffs, our operational and maintenance engineering staffs, our meteorological services and those concerned with air traffic control and the operation of navigational aids, I doubt if their training and their overall efficiency can be bettered in any other country.

Moreover, our two airline corporations have their own safety committees, whose duty is to investigate thoroughly every incident and accident which happens in their respective organizations.

All this is surely very encouraging and, to end, can I give greater assurance than to say that, in spite of what I know as the result of fifteen years' work connected with the unfortunate side of aviation, I still use the aeroplane as a means of transport when it is convenient to do so?

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III. SAFETY ON THE RAILWAYS

by

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Chief Inspecting Officer of Railways, Ministry of Transport and Civil Aviation

Monday, 8th March, 1954

I am going to tell you a little this evening about the working principles and methods which underlie the high standard of safety which is characteristic of railway travel to-day. The standard is much the same in all countries but I am going to speak mainly of the British ways of applying these working principles, not because they are the only good ways but because we are all more familiar with them. I should also mention that British safety methods have been developed to cope with the densest traffic in the world, with the possible exception of that in Belgium.

I will not make comparisons with other modes of transport, the conditions and circumstances of which are so different, but I will begin by giving you a few —very few—broad figures, so that the publicity which is invariably given to a serious railway accident may be viewed in its true perspective. The public concern when a serious accident occurs is, however, perfectly natural because a safe journey by rail has come to be taken for granted and the sudden impact of what may be a heavy casualty roll is particularly distressing.

In the seven post-war years 1946–1952 331 passengers lost their lives in accidents involving trains in Great Britain, including the 108 who were killed in the disastrous double collision at Harrow in 1952. The number of passenger journeys during the seven years was between 11 and 12 thousand millions, and passenger miles were more than 180 thousand millions. There was thus one passenger fatality for every 35 million passenger journeys and one for every 544 million passenger miles; if, therefore, you travel by rail three times a week you will probably be killed before you are 230 thousand years old. No one, however, would say, least of all the railways themselves, that this record could not and should not be improved.

When you come to think of it, the standard of safety on the railways *should* be very high. Track, signalling and rolling stock, are maintained and worked by a specially trained and disciplined staff who are organized under one management and are controlled and guided by stringent rules and long standing professional traditions. Railway trains run on a private fenced track, and the very nature of a railway and its equipment lends itself to the provision of technical safeguards of all kinds.

GOVERNMENT REGULATION

Although the responsibility for safety of operation must rest with the railway management, most governments exercise some degree of supervision of railway safety. In Great Britain, the Railway Inspectorate of the Ministry of Transport

and Civil Aviation has exercised statutory supervision of railway safety for the past 114 years. The Inspectorate was first established in 1840 under the Board of Trade, and was transferred to the Ministry of Transport when the department was formed in 1919. The duties, responsibilities and independence, of the Inspectorate were not changed when the railways were nationalized in 1948, and the past Acts affecting safety are applied to the British Transport Commission, just as they were to the former companies. Indeed the principles and methods of the Inspectorate and the general form of their reports have changed little since the earliest days.

Broadly our work falls under two main heads: inspection of new works on passenger lines, as a preliminary to the Minister's statutory approval, and accident investigation. The inspection work, which never comes into the public eye, is very important and confirms the fact that railway construction, in all aspects affecting safety, is up to the best standards of the day. These are codified in a published document entitled *Requirements of the Minister of Transport for Passenger Lines and Recommendations for Goods Lines*. The *Requirements* were first issued in very simple form in 1858 and have been revised periodically as technique has developed, latterly in close consultation with the railways. The last revision in 1950 was particularly thorough as there had been much progress in signalling since the last issue in 1928.

These government requirements are nothing like an elaborate treatise on railway engineering and signalling practice. Important basic standards are prescribed, and much discretion is left to the responsible engineers in giving effect to them. Provision is made for relaxation of the requirements at the discretion of the inspecting officer to meet special conditions. Once new works have been approved the Minister has no jurisdiction over their maintenance—for which the responsibility rests with the railways. Nor has he any jurisdiction over the construction of rolling stock, except on tube lines, or over the qualifications of the operating staff.

Our train accident investigation procedure is based on the reports which the railways are obliged to furnish to the Minister on practically every accident on or affecting a passenger line; certain mechanical failures also have to be reported. The average number of accidents reported yearly for the seven years 1946–1952 was 1,253 and the figure for 1952 was 1,243, including 416 collisions and 210 derailments. The great majority of the accidents reported are minor cases, and only a small proportion find their way into the newspapers.

The accident reports are examined by an inspecting officer, and where necessary fuller information is obtained and sometimes the railway officers are asked to discuss remedial measures with the inspecting officers. Formal inquiries are held into the more serious accidents and almost always when a passenger is killed, but inquiries are often held where there have been no personal injuries if the circumstances warrant a detailed investigation and published report. The decision to hold an inquiry into any particular accident generally rests with myself, and in recent times fifteen to eighteen inquiries have been held annually by the four inspecting officers. The reports of these inquiries have to be published under

statute and are on sale by the Stationery Office. Their recommendations cannot be enforced by law, but the effect of a thorough investigation and discussion with the railway officers usually results in their acceptance. Reliance is thus placed on the co-operation of a responsible railway management with the Inspectorate in the pursuit of a common objective. In later years especially the relations between the inspecting officers and the officers of the railways have been marked by great mutual confidence, and quite a lot of consultation—in both directions—goes on behind the scenes. I must also mention our staff of four railway employment inspectors, whose main duty is to investigate accidents to railway servants, every one of which has to be reported to the Minister if it involves more than three days absence from duty. In addition to the reports on individual accidents, the safety record of each year is reviewed comprehensively with full statistics in a published Annual Report by the Chief Inspecting Officer.

Railway safety in 1874

We have copies of all the inspection and accident reports which have been made since we began our work in 1840, together with many other valuable documents on the subject of railway safety. Among them is a copy of your Society's *Journal* dated 22nd May, 1874, containing a long paper by one of my predecessors, Captain H. W. Tyler, on 'Simplicity as the Essential Element of Safety and Efficiency in the Working of the Railways'. He, like myself, was a Royal Engineer, as indeed have been all the inspecting officers right up to the present day.

The intrinsic safety of railway travel had already been established in Tyler's day. In the seven years 1868 to 1874 one passenger was killed in every ten million passenger journeys, which compares with the one in 35 million journeys which I have told you was the ratio for the seven years 1946 to 1952. The improvement in the intervening eighty years has thus been more than three-fold in the face of an increase of something like 50 per cent in train speeds and in traffic density. The improvement has been due almost entirely to the development of technical safeguards.

In 1874, however, the inspecting officers of the Board of Trade were not satisfied that the comparatively simple technical safeguards of that time were being applied as widely as they should have been. The main theme of Tyler's paper was that the task of the men should be made as simple as possible, but he stated that simplicity in working might often require complication in construction, and he went on to advocate in no uncertain terms the universal adoption of block telegraph working and the interlocking of point and signal levers. Some of the many companies were exemplary in this respect, but others strongly opposed the view of the inspecting officers, holding that the efficiency and discipline of the staff would suffer if their work were made too simple. This led Tyler to launch a strong attack in his paper on some of the leading railway personalities of the day, but the discussion was postponed, and I am sorry to say that I have no record of it, if it ever took place. I can assure you however

that the principle that signalmen should be assisted by every practicable safeguard has long been accepted.

Legislation, however, was necessary to bring about a universal recognition of these principles and an important Regulation of Railways Act was passed in 1889 after public opinion had been stirred by a serious accident at Armagh in Northern Ireland in which 78 passengers were killed. This new Act at last gave the Board of Trade power to order the adoption of the absolute block system, the provision of interlocking, and the equipment of passenger trains with continuous automatic brakes. Most railway companies had by this time installed these three great safeguards extensively, and by the passing of the Act they were established on a statutory basis as fundamental principles of railway working.

RAILWAY SIGNALLING

I now propose to tell you a little about the working of some railway signalling safeguards, which are designed in the main to prevent accidents which may be caused by genuine mistakes on the part of a trained and disciplined staff rather than by gross carelessness or negligence; they also include devices to prove so far as possible that the apparatus itself is functioning correctly. These safeguards have grown from the first two provisions of the 1889 Act, namely absolute block working and interlocking, and they are, of course, related to the braking characteristics of the trains which are covered by the third provision of the Act. I will therefore go on to a brief description of the working of railway brakes, and I will then say something about the observance of signalling before mentioning derailments.

The purpose of railway signalling may be defined as to keep traffic moving with the greatest possible freedom consistent with safety. The necessity for more or less elaborate signalling on a railway arises from the inescapable limit which is set to the braking power of a train by the comparatively low co-efficient of friction between a steel tyre and a steel rail. With the best of modern brakes, a steam passenger train cannot pull up from 60 m.p.h. on the level in much less than 600 yards. The stopping distance increases roughly with the square of the speed, and at 90 m.p.h., which is about the maximum speed generally used, it may be more than three quarters of a mile. Multiple unit electric trains can do rather better, but their stopping distances are of the same order. It is quite impossible, therefore, for trains to run at sight like motor vehicles on the road.

Block system—double lines

The necessary interval of space between succeeding trains is maintained by the ***block system***, which became possible with the invention of the electric telegraph in the 1840s. Before that, trains were worked by time interval, and it is not difficult to imagine the risks under this system. Unpunctuality and variation between station clocks was a direct source of danger.

Under the ***absolute block system*** the line is divided into ***sections*** by signal boxes or block posts, and only one train is allowed to be in a particular section

at any one time. Each block post is equipped with block instruments, which are really quite a simple form of telegraph apparatus. Modern block instruments have three indications, namely *Line Blocked*, the normal indication when no trains are about, *Line Clear* and *Train on Line*.

Imagine that a signalman wishes to send a train forward and that his instrument for the forward section is at *Line Blocked*. He must then ask the man at the next forward box for *Line Clear* by a specified bell code; this is called 'offering' the train forward. The forward signalman, if he has seen that the previous train has passed him complete, and has gone a specified distance, usually a quarter of a mile, beyond his first stop signal, can 'accept' the train: he does this by setting the block instrument in the rear box to the *Line Clear* indication, and this is repeated on his own instrument for the rear section.

Until this is done the rear signalman is not allowed to clear his 'starting' signal to admit the train to the section. When the train passes him he announces to the forward signalmen by another bell code that it is *entering the section*, on which the forward signalman changes the rear man's instrument to *Train on Line*. This indication appears simultaneously on the forward instrument, and the forward signalman must on no account restore the indication to *Line Blocked* and send back the *Train out of Section* bell code until the train has passed him and he has seen its tail lamp disappear to verify that no part of the train has broken away and been left behind in mid section.

The railways operate the block system under their own strict code of regulations which provide for all types of situations, including junction working, and as a general rule two trains are not accepted simultaneously to a converging junction unless the fouling point of the junction is protected by *two* stop signals not less than 440 yards apart. The regulations also lay down the action to be taken in many kinds of emergency such as trains running past danger signals, trains which have become divided, trains which are seen to have something wrong with them, and the signalman is also told what he should do if a train passes his box without a tail lamp.

Block system—single lines

What I have said so far applies to double lines where the trains always run in the same direction on a particular track. Where trains run in both directions on a single line special precautions have to be taken to prevent head-on collisions, which of course may have very serious consequences. What are called *token* methods have generally been adopted in this country. Before he enters a single line section a driver must have in his possession an object, or token, usually a metal tablet or staff inscribed with the names of the stations at each end. The tokens are kept in magazines forming part of special block instruments in the signal boxes, and the pair of instruments for a section are electrically interlocked through the lineside wires in such a way that a signalman cannot withdraw a token until he has received *Line Clear*. The interlocking also ensures that once a token has been withdrawn from either end no further token is obtainable unless the first token has been replaced in one of the instruments; the tokens and

the instrument locking gear for a particular section are so formed that a token for one section cannot be put into the instruments of another.

Possession of the token thus guarantees that no other train is in the section either moving in the same or in the opposite direction. The psychological effect of the token system has been so good that collisions on British single lines have been exceptionally rare.

Signals and interlocking

I will now say a few words about the signals themselves and elementary interlocking. Even small wayside stations in this country generally have at least two stop signals for each direction, a *home* signal at the approach to the station to protect trains standing or shunting there—and a *starting* signal at the forward end to control the entrance to the block section beyond. Even at moderate speeds in clear weather it is often impossible for a train to stop within the sighting distance of a signal, and it is therefore necessary to provide a cautionary or *distant* signal at braking distance from the first stop signal of a station. Distant signals are distinguished by yellow painted fish-tailed arms. They show clear only when the succeeding stop signals have been cleared for a train to run through the station into the section ahead; the caution indication can be passed but requires a prompt reduction of speed to enable the train to stop at the home signal if required. The distant signal is thus a very important one in high speed running. Signals can also indicate the direction to be taken by a train at diverging or facing junctions and in addition to these running signals, shunting signals are provided (generally low down on the ground) to control slow speed movements through crossovers and other points.

The interlocking of point and signal levers to prevent inadvertent false moves was required by the Board of Trade *Requirements* for new works in Tyler's day, but not retrospectively, and much in this direction still remained to be done. The provisions of the *Requirements* on interlocking are not so very different to-day, and I will quote a few lines from them in illustration of the principles which are now universally applied:

> Point and signal levers to be so interlocked that the signalman cannot clear a signal for the movement of a train unless he has set the points in the proper position for it to pass, and bolted them as necessary; that it shall not be possible for him to clear at one and the same time any two signals, which may lead to a collision between two trains; and that after having cleared the signals to allow a train to pass, he shall not be able to move any points connected with or leading to the line on which the train is moving, until the signals have been replaced. Points also, where practicable, to be so interlocked as to avoid the risk of a collision.
>
> Distant signal levers to be so interlocked that they cannot be pulled until the levers of all related Stop signals have been pulled. . . .

You will note the reference to bolting of points. The *Requirements* lay down that all facing or diverging points must be bolted, so that they cannot shift and cause a derailment. The bolt is generally worked by a separate lever and the act of bolting or unbolting raises a long bar from alongside the rail, so that it is

impossible to cause a derailment by unbolting a set of points when a train is passing over them.

The levers at signal boxes are concentrated in a 'locking frame' and in manual boxes and in the earlier power boxes with miniature levers the locking is mechanical, but in the more recent large power signal boxes it is achieved electrically. Lever interlocking is of course universal to-day, though there is still room for differences of opinion in its detailed application, and if locking is made too restrictive freedom of movement may suffer with resulting traffic delays.

Modern signalling controls

The simple form of block working which I have described, combined with the interlocking, in the hands of skilled and conscientious signalmen has afforded a high degree of security and is still in use with little or no elaboration on many lines where the pressure of traffic is not too severe. It does, however, give room for human error, and cases have occurred where a signalman has wrongly 'cleared the block' under the impression or even conviction that a train has passed him, when in fact it has broken down in mid section. Or again he has cleared the block and accepted a train when a previous train which is waiting at his home signal out of his clear view has been forgotten. Again a train or light engine which is standing on the running line, perhaps during a shunting movement, may be forgotten and the signals protecting it cleared for another train.

I should mention however that the railway rules require the driver or fireman of a train or engine detained on a running line to proceed immediately to the box to remind the signalman of its presence. This is the well-known Rule 55. Again, if a train is stopped for any reason in mid section one of its crew has to go back for three quarters of a mile to protect it by detonators and hand signals in case there is a breakdown in block working, or a following train passes signals at Danger. Indeed wherever possible railway rules provide for a second line of defence against the consequences of human failure. Signalmen have also been known to lower the starting signal to admit a train to the section without *Line Clear* from the box ahead, or have even omitted to restore signals to Danger after a train has passed.

There is more likelihood of mistakes and confusion when trains are following each other closely on busy lines or at complicated junctions where a signalman may have several trains on hand at once, especially in foggy weather or at night. Towards the end of the last century it was realized that something more than the simple block working was required for safety under these conditions, and quite efficient systems were devised for interlocking the block instruments with the signal levers.

These lock and block systems had become much elaborated on some railways in the early 1900s. They have contributed much to the safety of dense traffic and are still quite extensive though declining in use. They are clumsy in design by modern standards, but the same principles have been adopted in the standard modern *block controls*, which are in use in one form or another on most of our important main lines.

The latest methods of co-ordinating the working of the signals and block instruments were included in the *Requirements* for the first time in 1950, and they are based on lessons learned from past accidents. Among the methods recommended are the release of the starting signal, for one operation only, by acceptance of the train from the box in advance; the prevention of such acceptance unless the first stop signal at this box is at Danger and the distant signal at Caution; the interlocking of successive Stop signals worked by the same box so as to ensure that none can be cleared unless the next ahead is at Danger; and the provision of a Home berth *track circuit*, which when occupied exhibits and maintains the *Train on Line* indication on the block instrument of the box in rear. Finally there is the control which prevents the acceptance of a train unless the previous train has passed through the block section and has occupied and cleared a track circuit at the forward end. This is known as the 'Welwyn' control, as it was introduced after a serious collision at Welwyn Garden City in 1935.

Track circuits

I would draw your special attention to the two references to track circuits. The track circuit, which was perfected about fifty years ago after much experiment, is the basis of modern signalling and enables the trains to take a hand in their own protection.

A section of the track, varying perhaps from 20 or 30 yards to three quarters of a mile or more, is insulated at the rail joints from adjoining sections, and a low voltage current is passed continually through the rails to hold closed the contacts of a relay or electrically operated switch; wooden sleepers generally provide quite sufficient insulation between the ends. A train on the section short circuits the current through the wheels and axles and the relay opens its contacts. I do not think it is difficult to see that by a succession of relays and interconnected electrical circuits a track circuit may be made to perform many signalling functions. One of the most important is to indicate to the signalman the presence and position of a train, either by a simple indicator in the box showing *Track Clear* or *Track Occupied*, or, where there are more than a few track circuits, by an illuminated diagram of the lines on which the position of a train and its progress is shown by bulls-eye or strip lights.

The occupation of a track circuit also locks the signal or signals in rear at danger and it may also lock points which might lead to a conflicting movement. Track circuits are also often used to prevent the unbolting of facing points under a train, and in power signalling installations they can hold a succession of facing points in the correct position until a train has passed clear of them.

Continuous track circuiting and multi-aspect signals

The extent of track circuiting may vary, from one or two track circuits at a simple wayside layout to remind the signalman of a train standing out of his clear view, to the complete track circuiting of large and complicated layouts. Track circuiting can also be continuous through a section or sections and is

then usually combined with multi-aspect colour light signals which are automatically controlled by the passage of the trains. Three-aspect signals show green for clear, red for stop, and yellow when the next signal is at red. In congested areas it is often necessary to space signals so closely that there is insufficient braking distance between the yellow aspect of one signal and the red aspect of the next, and a fourth aspect is then used, double yellow (preliminary caution) leading through yellow to the red.

Some British examples of continuous track circuiting are the lines from Liverpool Street to Shenfield, Waterloo to Hampton Court Junction, and London to Brighton, soon to be completed. Nor must I forget the early installation between Woking and Basingstoke which still operates with semaphore signals. In all of these manual block working is dispensed with, but they conform with the Absolute Block provision of the 1889 Act in that the occupation of any track circuit is made, in the words of the *Requirements*, 'to place and maintain at danger sufficient signals in rear to provide the necessary space interval'.

Signalling at York

I must also mention the 48 miles of continuous track circuiting between York and Darlington where there are four-aspect colour lights to give the braking distances required on one of our fastest stretches of line. The electro-pneumatic signalling installation at York which was inspected and brought into use in 1951 is the largest and most elaborate in the world, and nearly 6 miles of route and 33 miles of track through 16 station platforms and an exceedingly busy and complicated series of junctions is controlled from one central signal box in which the signalmen work entirely by the track circuit diagram without seeing any of the trains. This box has replaced no less than eight manual boxes. The signalmen have turn-button switches to work the signals only, and once the switch has been turned to clear a signal for any one of the 828 different routes all the necessary points move automatically and are proved in their correct positions before the signal will finally clear. All the switches are free to be turned at any time, but the electrical relay interlocking and the track circuit controls will not allow a signal to change from red or points to move unless all is in order for them to do so.

The task of the signalmen at York is thus exceedingly simple once they have mastered the layout and the traffic movements required, and it is practically impossible for them to make a dangerous mistake, though mistakes can lead to traffic delays. I think that Tyler would have regarded the remarkably successful York installation as the ultimate expression of the principle of simplicity in working achieved by complication of construction. The apparatus and electrical circuits at York are indeed complicated and require unremitting attention to their maintenance—there are nearly 3,000 relays in the box, connected by 400 miles of wire—but as has always been an invariable principle in all railway safety equipment they are arranged so that any failure will be on the safety side, and will therefore result in delay and not danger; this is also stipulated in the *Requirements*.

Proving devices

All signalling installations embody devices to prove that the apparatus is working as intended. One of the simplest is the mechanical detection of facing points to ensure that the points on the ground have responded correctly to their levers. Notched slides are provided in the run of the signal wires which are only free to move if cross slides rigidly connected to the point blades are in their correct position to the nearest eighth of an inch. Thus if a point blade has been prevented from closing by a piece of stone ballast or if the point rodding is broken or out of adjustment, the corresponding signal arm cannot move to clear, although its lever may have been freed in the frame interlocking by moving the point lever to its correct position: facing bolt points are similarly detected to ensure that they have gone home. Nowadays point detection is often achieved electrically.

Electrical repeaters are provided in the signal boxes to enable the signalmen to make sure that signals have responded correctly to their levers, and the proving of the distant arms at caution before a train can be accepted is done through the repeater circuit. Oil-burning signal lights are also repeated 'in' or 'out' by means of thermo-couples. As another example of proving, a colour light signal is often held at red if the bulb has failed in the red or yellow indication of the next signal ahead.

RAILWAY BRAKES

What I have said so far relates in the main to the task of the signalmen in keeping trains apart from one another and to the methods which are applied to prevent signalmen's mistakes. They have been evolved by a vast amount of invention, research and experiment, by the engineers of the railways and of the railway signalling firms, and in this country the Institution of Railway Signal Engineers has contributed a great deal to the advancement of technique. None of these safeguards, however, can be effective unless the drivers control their trains in accordance with the signal indications, and this leads me first of all to tell you something about the working of railway brakes.

In the middle of the last century the only brakes available, even on passenger trains, were the engine brake, hand-screw or steam operated, and the hand brakes on the vans, and the speed at which trains could be worked in safety was severely limited by the inordinately long stopping distances. It was soon recognized that the maximum braking power could only be developed if every wheel on the train was braked from the engine. After many experiments, which included some with extraordinary contraptions of chains running along the train, the historic brake trials at Newark in 1875 which were sponsored by a Royal Commission, set a seal on the pneumatic methods which are universal to-day under two distinct systems, namely the *vacuum* brake, and the *compressed air* brake, of which the Westinghouse type is the best known.

Non-automatic brakes

Both systems have a continuous pipe throughout the train known as the train pipe, connected between the vehicles by the familiar hose couplings. The earlier

types of continuous brake were worked on the simple or 'straight' principle. With the vacuum system air was exhausted from the train pipe and the connected brake cylinders on the vehicles by an ejector or pump on the engine to apply the brakes and hold them on, and the brakes were released by destroying the vacuum again. With the 'straight' air brakes, compressed air was forced into the brake cylinders from a reservoir on the engine which was kept charged by a steam pump, and the pressure was released to take the brakes off. This arrangement was very simple, and afforded good control, but it had the grave disadvantage that all brake power was lost if the train broke apart, or even if there was a serious leak in the system.

Automatic brakes

The arrangement was therefore reversed with some added complications so as to require the maintenance of full vacuum or pressure in the train pipe to hold the brakes off, and a reduction of vacuum or pressure to apply them: release is effected by restoring the vacuum or pressure which also serves to recharge the brake reservoirs under the vehicles for the next application. This is the *automatic* brake, automatic in the sense that it applies itself with full power on both parts of a train which may break apart and, as a corollary, the brake goes on if there is a leak of any consequence in the system.

The automatic brake also has the advantage that it can be applied in an emergency by the guard by means of a simple valve, though he cannot release it again. It also furnishes a convenient means of communication between passengers and the driver, as is a statutory obligation in this country. When a communication chain is pulled a small valve is opened to the train pipe and gradually applies the brake throughout the train. The consequent drag is felt on the footplate and the reduction in vacuum or pressure is shown on the driver's gauge. When this happens, he is required by rule to assume that the chain has been pulled and to stop the train.

You will see from the foregoing that the automatic action of the brake is fundamental to the safety of railway operation. In the Board of Trade *Requirements* of 1877 special stress was laid on the installation of the continuous automatic brake on all passenger trains and, as I have mentioned, it was made compulsory by the 1889 Act. This was a direct result of the Armagh disaster in which an excursion train of 15 vehicles, fitted throughout with the non-automatic brake, failed to reach the top of a steep gradient. The train was divided to enable it to proceed in two portions, but the rear ten vehicles were not well secured and ran back for 1½ miles to Armagh. The runaway vehicles crashed at great speed into a slowly moving passenger train which had left Armagh twenty minutes after the excursion train under the time interval system. The company concerned was one of the few which were still not working Absolute Block and the Armagh accident also led to its being made compulsory.

Modern improvements

Railway brake development since those days has consisted mainly of refinements in detail, some of them to give a quicker response of the train brakes to the

driver's control valve and so reduce stopping distances and avoid snatches or surges in a long train. In recent years instantaneous action with great nicety of control has been obtained on electric trains by using the non-automatic air brake with electric control, and this is known as the electro-pneumatic or E.P. brake which is universal on the London Transport trains. In case you might think that this was retrograde—and illegal—I would tell you that such trains are invariably equipped with the automatic air brake as well.

Vacuum and air brake systems

The vacuum brake was standardized for steam hauled trains in this country when the railways were grouped into four large companies in 1923, and the main reason was the preponderance of the vacuum equipped lines at that time; though several large companies, notably the North Eastern, the Caledonian and the North British had standardized on Westinghouse. In North America, the home of George Westinghouse, the air brake is universal and it is also used on the majority of the Continental railways where the very distinctive beat of the Westinghouse pump on the engine is a familiar sound to travellers.

The driving force of the vacuum brake at the usual 21 inches of vacuum is about 10 lb. per square inch only, but it can be made to develop the same, or nearly the same, braking force as the 70 lb. per square inch or more of the compressed air brake, but only at the expense of heavier and clumsier equipment under the coaches. Vacuum equipment, however, is simpler and on the whole cheaper in first cost and maintenance. Both systems are equally reliable and failures of the continuous brake to act have been exceptionally rare. The comparative advantages and disadvantages of the two systems are fairly well balanced, but I cannot help thinking that it is better engineering to do the job with 70 lb. of pressure than 10 lb. of comparatively sluggish 'suck'. I am not alone in holding this view, and it is possible that if we in this country were starting afresh to-day we should go for the air brake with its more lively response to application and release by the driver. The Westinghouse air brake is the standard for our electric trains.

OBSERVANCE OF SIGNALS

I have told you a little about the equipment which is designed to prevent signalmen from sending a wrongful message to the drivers through the wayside signals which they control but, as I have said, it is equally important that the signals should be observed, interpreted correctly and obeyed by the drivers.

As one means to this end, drivers are not allowed to be in sole charge on a particular route until they have learned all its characteristics including the location and meaning of the signals, the gradients and the local speed restrictions imposed on account of curvature or for other reasons; if, as sometimes happens, a driver has to go forward over a route with which he is not familiar he has to have a conductor driver with him, or, in other words, he takes a pilot.

Every endeavour is also made to locate the signals to give the best possible view of them from the footplate, and the modern colour light signal is a great improvement on the older semaphores in this respect, especially at night. As it

only has to be seen from a train on a particular set of rails, its beam can be narrowly focussed to give great brilliance and penetrative power, which is especially valuable in mist or fog. Colour lights also enable the signal aspects to be greatly simplified at junctions and complicated layouts, and the arresting colour light distant signals showing yellow or green which have been installed extensively in semaphore areas on high speed routes have been much appreciated by the enginemen.

Automatic train control

Safety, however, still depends on the personal vigilance of drivers in all weathers, but it can be reinforced by apparatus to furnish a positive link between the wayside signals and the footplate, which is generally known as *automatic train control*. It can take many forms and has a near relation in the exceedingly costly track and locomotive equipment used on some American railways to repeat the indication of multi-aspect signals continuously in the cab. Automatic train control, however, is by no means universal on American and Continental railways, and in this country at present only a comparatively small proportion of the route mileage is so equipped.

Warning control on main lines

The view is generally held that the type known as *warning control*, which gives an audible warning in the cab and a cancellable brake application when a distant signal is passed at Caution, is best suited to main line conditions in this country. The great value of warning control lies in its ability to prevent the serious type of accident which may result if speed is not reduced at a caution signal—a notable example was the disaster at Harrow—but the proportion of accidents which it can prevent is comparatively small, about 10 per cent of all the serious accidents in this country in the last forty years. It is by no means the panacea for all the risks of train operation, which its rather high-sounding and perhaps misleading title may suggest to the less well-informed.

This fact, considered in relation to the cost of installation, has been one of the reasons for the hesitancy of some of the former British Railway Companies to adopt automatic train control, in spite of strong pressure from government recommendations. Furthermore, with automatic train control it is a case of all or nothing on long lengths of route, whereas other signalling safeguards can be applied piecemeal in the course of renewals with immediate local advantage to safety and traffic movement.

A notable exception to this outlook was that of the former Great Western Railway, and the London Midland and Scottish Railway had gone in for warning control on a smaller scale. On nationalization in 1948 the principle was accepted at last that drivers on all the main lines of British Railways should be given their share of modern technical aids to safe working, and the British Transport Commission then began to develop apparatus to combine the best features of the Great Western contact system and the London Midland and Scottish magnetic non-contact system to meet conditions in all parts of the country on steam and electrified lines.

As I expect you know the development of this apparatus has now reached an advanced stage and is in large scale trial in day-to-day service on the East Coast main line. The trials may have to go on for some time yet in order to establish the very high standard of reliability which is required, but directly this stage is reached the Commission propose to extend warning control progressively to all the more important routes of the country.

Stop control on urban electric railways

Another form of automatic train control, namely *stop control*, is essential to safety under the special conditions of the London Transport and other similar railways. On the London Transport lines every signal has a trip lever on the ground which engages with and opens a cock on the train pipe to apply the brake with full force if a signal is passed at danger. The many signals, and the track circuits controlling them, are so spaced that a train overrunning a signal at danger will be stopped by the trip well clear of a train ahead. This combination of effects can only be achieved where all the trains run at practically the same moderate speed, and on the London Transport lines, which are all continuously track circuited with colour light signals, the free movement of closely spaced trains in great safety has been brought to a fine art if not to an exact science.

DERAILMENTS

On the question of derailments I should say first of all that the tendency of a flanged railway wheel is to stay on the rails, provided always that the designed weight on the wheel is maintained during running within reasonable limits; and the proper distribution of weight in running is a very important function in the design and adjustment of railway vehicle springs which has little or no counterpart on the road. Furthermore, the side control springs of the leading bogies of locomotives play a very important part in the distribution of the flange pressures so that no wheel flange takes an excessive share in guiding an engine round a curve at speed or in keeping it steady on the straight. Much thought has been given to the design of locomotive control springs, backed up by experiment and sometimes bitter experience, but scientific analysis of the interaction of the locomotive and the track at speed is a very complex problem, and we can hardly say that knowledge on the subject is complete.

The necessity for a strong, stable and well aligned, track with the minimum of inequalities of cross level goes without saying, but track maintenance has to contend with all the vagaries of climate and sub-soil conditions, and locomotives and rolling stock have to be designed to adapt themselves to a certain amount of inequality. Indeed the track and locomotive must be considered as component parts of one machine, and the more perfectly designed and maintained is the one the less perfect can be the other. In industrialized countries the standard of track and locomotive design and maintenance is such that speeds of 80 or 90 m.p.h. and more can be held in perfect safety, and it is only on the rare occasions when adverse factors combine exceptionally at a critical moment that a derailment occurs on plain track.

Breakages and failures

I am not of course speaking of derailments which may be brought about by mechanical or material failures such as the breakage of an axle or a tire or the failure of engine motion work. With the constant necessity to keep weight and bulk down these parts have to be highly stressed and their design, and the steel of which they are made, have been constantly improved by the engineers and the metallurgists in order to minimize the risk of failure in service. As in other branches of engineering, the main cause of trouble is the growing or creeping flaw which may be started by a tool mark during manufacture or perhaps by corrosion and, if it is undetected, may continue until the cross section is so reduced that the part can no longer withstand its normal stress.

By good design and workmanship the opportunity for flaws to develop can be reduced, but they cannot be prevented absolutely, and safety depends on their detection in good time by rigorous examination of the parts during the course of workshop repairs. Flaws in certain positions, for instance in railway axles at the point of high stress where they are pressed into the wheel, are extremely difficult to detect visually or by magnetic methods, but in the last few years periodical testing by methods using ultra-sonic vibrations has met with marked success, and carriage axle failures, which were once quite a source of anxiety, have now been reduced in this country to one or two in the course of a year.

The steel of which the rails are made has to be a compromise between hardness to resist wear and toughness to resist shock, and it is impossible to avoid occasional breakages under traffic. We have fewer rail breakages than the railways of some other countries, and they seldom cause serious derailments, although there was one from this cause at Watford last month which, as you probably know, is under inquiry. Prevention of this kind of trouble is largely a matter of good maintenance of the track to avoid undue flexure of the joints and timely renewal of worn or corroded rails, coupled with conscientious daily examination by the length ganger. Here again ultra-sonic methods of testing with light and portable equipment have met with considerable success in the detection of flawed or cracked rails, particularly at the joints, and this use is being extended.

Examinations

Apart from actual breakages, derailments can also be caused by parts coming adrift either on the rolling stock or on the track. Nowhere more than on a railway does safety depend on conscientious workmanship to the last detail and rigorous inspection and examination at frequent intervals, and even a missing or badly fitted split pin can have very serious consequences. The examination and repair procedure for earthwork, structures, tunnels, bridges, track, signalling equipment, locomotives and rolling stock, is very highly organized, down to a daily examination of vital parts, and as you all know from the tapping of wheels to search for the false ring of a broken tire trains are also examined during the course of a journey.

CONCLUSION

However good the organization may be the safe maintenance of the many and widely differing forms of railway equipment depends in the final outcome on the knowledge, skill and sense of responsibility, of the subordinate staff, much of whose work has to be done without the possibility of close supervision—just as the safety of train working has to be based primarily on the watchfulness and integrity of solitary signalmen, drivers, guards and others, and these can never be replaced entirely by technical safeguards, though they can do much to help. The railways of all countries have built up a strong traditional regard for safety among their officers and men of all grades, but so long as they are managed and worked by fallible human beings I am afraid things will go wrong from time to time. The occasions are comparatively few in relation to the speed and volume of the traffic carried, and this is largely because the lessons of past failures have been applied to good purpose, either by improvement in working methods, equipment, or engineering technique, or by taking remedial measures of a different kind where there is inefficiency or neglect of duty.

What of the future? The inherent capacity of railways to carry heavy loads of passengers and freight at high average speeds seems to assure their continuance as a basic means of transport for many years to come, but in this 130th year in their history of public service it is difficult to foresee any startling innovations in their technical safety equipment. Radar for instance has no application to the prevention of railway collisions, at any rate in its present state of development, despite its proved contribution to safety at sea and in the air, and radio communication has very doubtful value to the safety of train operation though it has been found useful in some types of railway control work. We must, of course, anticipate a continuous advance in general engineering knowledge and practice, of which I am sure that full advantage will be taken by the railways, aided by their costly research departments, but apart from that it seems that future progress will lie in the wider and wider extension of proved technical safeguards in the course of renewals and modernization, and their refinement in detail and adaptation to changing conditions of operation. I will not attempt to forecast the future trend of Safety on the Railways. Almost all accidents are preventable in one way or another, and safety should improve with the growth of knowledge and experience, and as preventive equipment is more widely installed; but there are few accidents in which the human element can be disregarded and a great deal will always depend on morale and discipline—in the highest meaning of that sometimes unpopular word. Modernity and smartness of rolling stock, equipment, and surroundings, coupled with smart and punctual working, act as a strong tonic to the staff in the highest and the lowest quarters, and in this way as well have their bearing on safety; but I think we must also remember that changes in social and industrial conditions bring their distractions with them—on the railways no less than elsewhere—and it may be that the need for technical aids to safe working will become more pressing in the future than it has been in the past.

GENERAL NOTES

TWO ANNIVERSARIES

The anniversaries of the deaths of two men who were well known to the Society occurred recently.

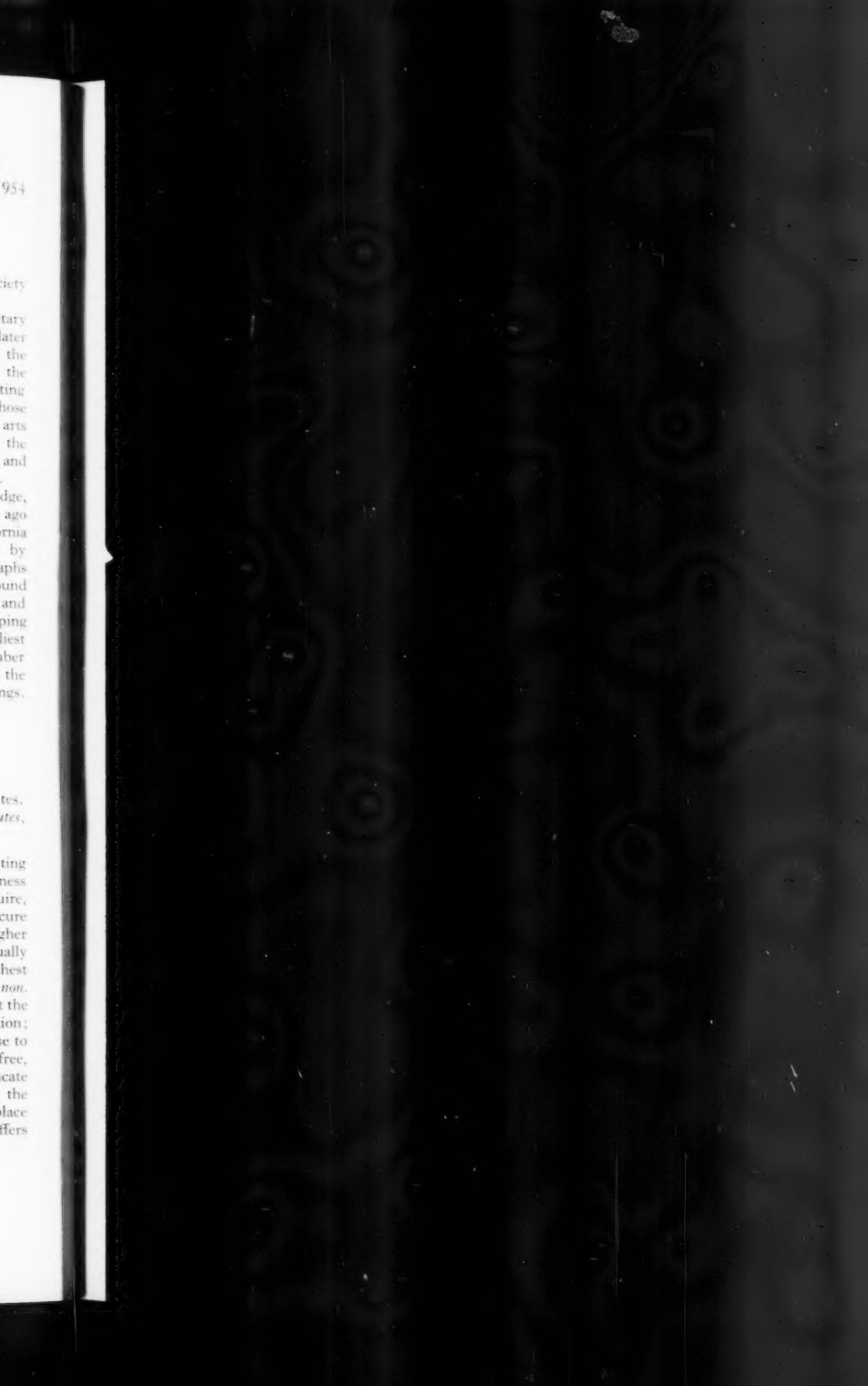
Arthur Aikin, who died one hundred years ago, became the Society's Secretary in 1817; he was a founder of the Geological Society, and first Treasurer, and later President, of the Chemical Society which was founded in 1841 at a meeting at the Society's House. During the twenty-three years in which he was Secretary the change in the Society's methods occurred which resulted in the Society's departing from its original role of a purely premium-giving body, and becoming one whose main object was to be the dissemination of information about the industrial arts and sciences: the practice of including courses of lectures as a regular item in the Society's arrangements, which heralded this change, was due to his initiative and he personally delivered numerous courses on various branches of manufactures.

Eadweard Muybridge (the name is his own version of Edward Muggeridge, changed since he considered the former more Anglo-Saxon) died fifty years ago and was an early photographer of motion. He had an adventurous life in California and Central America, and was first led to photographing moving objects by Governor Leland Stanford, a wealthy railway owner. Muybridge's photographs of a moving horse which showed that at one point all four feet were off the ground enabled Stanford to win a bet of $25,000. He lectured to the Society in 1882 and showed his 'Zoopraxiscope', a revolving drum with photographs of horses galloping on it which were projected on a screen. This demonstration was one of the earliest in this country of what was, in fact, the first cinematograph. Fellows may remember that when sound was added to the moving picture, the first demonstration of the ultimately successful process in this country was given at one of the Society's meetings.

FROM THE JOURNAL OF 1854

VOLUME II. *26th May*, 1854

From a letter On The Examination of Members of Literary and Mechanics' Institutes.

The Society's examinations, originally intended for members of mechanics' institutes, were finally established in 1856.

Sir,—It is very desirable that the real question now under discussion respecting examinations and diplomas should be cleared of all difficulties and indefiniteness and set plainly before the public. . . . The proposal is, on the one hand to require, and on the other hand to give, such a diploma to the working classes as shall secure to the employer the intelligence he expects and pays for. It is required in the higher classes of society, in the law, in the church, and in medicine,—why is it not equally applicable to the humbler? It does not propose to set up every office to the highest bidder by examination, but to require a certificate of examination as a *sine qua non*. Every applicant for office must come with a diploma in his hand. Now this is what the cause of education requires; it is idle to say that it is enough to offer a good education; there are thousands and tens of thousands who do not know its value. It is no use to talk of compelling parents to send their children to school; the country is too free, or imagines itself too free, to bear it; but you may and might require a certificate from all candidates for office, and by so doing you will bring home to parents the money value of education; you would render a service to the bestowers of place and patronage; and you would do more than laws of compulsion, or the best offers of a good education for its own inherent value will ever be able to do.